DRAFT

INITIAL
GROUNDWATER CONDITIONS WORK PLAN

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SECTION 1.0
INTRODUCTION

Atlantic Richfield Company has prepared this Draft Initial Groundwater Conditions Work Plan ("Work Plan") to conduct initial investigations that would assist in evaluating potential ecological and human health risks associated with mine-related groundwater resulting from historic mining, milling and leaching operations at the Yerington Mine Site. The area north and west of the mine site is the focus of this initial investigation because recent sampling of domestic wells indicates that uranium concentrations in groundwater locally exceed the maximum contaminant level (MCL) of 30 micrograms per liter (ug/L). Investigations proposed in this Work Plan would be conducted pursuant to the Quality Assurance Project Plan (QAPP; Brown and Caldwell, 2002b). The following communications between Atlantic Richfield and the U.S. Environmental Protection Agency (EPA), Nevada Division of Environmental Protection – Bureau of Water Pollution Control (NDEP) and the U.S. Bureau of Land Management (BLM) have resulted in this Work Plan:.

- October 26, 2004 letter from Atlantic Richfield to NDEP entitled: Proposed Groundwater Investigations for the Yerington Mine Site;
- EPA Preliminary Response to Comments on the Proposed Offsite Groundwater Investigation;
- November 24, 2004 letter from Atlantic Richfield to NDEP entitled: Response to Comments on Proposed Groundwater Investigations for the Yerington Mine Site; and
- Teleconference between Atlantic Richfield, EPA, BLM, NDEP and other members of the Yerington Technical Work Group.

Initial groundwater investigations conducted as part of this Work Plan would provide the basis for developing an improved conceptual hydrogeologic model for the area around the mine site and, subsequently, a more comprehensive Groundwater Conditions Work Plan. Initial and subsequent groundwater investigations would address the Data Quality Objectives (DQOs) described in the *Draft Final Groundwater Conditions Work Plan* (Brown and Caldwell (2003a). Modified DQOs for proposed initial groundwater investigations are presented in Section 2.0 of this Work Plan.

1.1 Location

The Yerington Mine Site is located west and northwest of the town of Yerington in Lyon County, Nevada (Figure 1). The Walker River flows northerly and northeasterly past the mine site, between the site and the town of Yerington. The river is within a quarter-mile of the southern portion of the site, and the distance between the site and the river increases to the north. Highway 95A is also located between the mine site and the town of Yerington (Figure 1). The Paiute Tribe Indian Reservation is located approximately 2.5 miles north of the site.

The Yerington Mine Site is located in Mason Valley and the Mason Valley hydrographic basin (no. 108) within the Walker River watershed. Agriculture has been the principal economic activity in Mason Valley (principally hay and grain farming, with some beef and dairy cattle ranching). Local onion farming is also present in the area. Surface water diversions from the Walker River and groundwater pumping provide the irrigation water for these agricultural activities. Agricultural irrigation immediately north of the mine site is anticipated to significantly influence groundwater flow conditions.

1.2 Past Mining Operations and Current Conditions

Mining, milling and leaching operations for oxide and sulfide copper ores from an open-pit in the southern portion of the mine site were conducted between 1953 and 1978 by Atlantic Richfield's predecessor, the Anaconda Mining Company. Waste rock piles were constructed to the south and to the north of the open pit. Tailings impoundments and process solution evaporation ponds were constructed north of the pit and the mill/precipitation plant areas. The milling process for oxide and sulfide ores varied. Oxide ores were crushed and vat-treated with sulfuric acid that was produced from an on-site Acid Plant. The resulting copper sulfate solution was decanted and the remaining solids were placed in the tailings ponds. The copper sulfate solution was subjected to "iron laundering" in which the copper in solution exchanged with iron, resulting in a copper precipitate. Residual solutions, containing elevated concentrations of iron and sulfate, were conveyed to evaporation ponds at a rate of about 700 gpm (Seitz et. al., 1982).

Sulfide ores were finely crushed, and copper sulfides were recovered using a flotation process with the addition of lime to achieve a neutral pH. Residual solids were then placed in the sulfide tailings ponds. Copper concentrates from the milling process were dried and shipped off-site for smelting. Fine-grained tailings were transported to the ponds as a slurry, and the liquid fraction was recycled for use in further milling. Seepage from the northernmost tailings pond was collected in a peripheral ditch and recycled along with the liquid fraction of the tailings fluid. During mining and milling operations, the tailings deposition areas and associated evaporation ponds and containment ditches were progressively expanded to the north to accommodate the need for increased tailings capacity. Given the mineralogical characteristics of the ore and waste rock mined from the Yerington open pit, naturally-occurring radioactive minerals appear to have been concentrated in portions of the tailings areas and evaporation ponds.

Arimetco, Inc. acquired the property in 1989, and initiated leaching operations at five lined leach pads located around the site (Figure 2), including the re-handling and leaching of previously deposited waste rock north of the pit. Arimetco also constructed and operated an electro-winning plant with associated solution ponds located south of the former mill area (Figure 2). Some Arimetco leach pads and solution ponds were constructed on the pre-existing oxide tailings areas. Arimetco ceased mining new ore and leaching operations in November 1998, and continued to recover copper from the heaps until November 1999 (Joe Sawyer, SRK; written comm.., 2003). Since the end of mining and leaching operations by Arimetco in 1996 to the present, the State of Nevada has managed heap process fluids by re-circulation and evaporation.

Beginning in 1986, Atlantic Richfield managed groundwater by installing and operating a pumpback well system located along the northwestern margin of the mine site. Lined pumpback evaporation ponds were constructed in 1986 to evaporate mine-related groundwater at the site. Past mining and ore processing activities at the Yerington Mine have created the current site conditions, with the mine units and process areas shown in Figure 2. The following mine units may be potential sources of constituents of concern (COCs) to groundwater via leaching of surface materials by meteoric water and infiltration through the unsaturated (vadose) zone:

Tailings Areas
- Oxide (Vat Leach) Tailings
- Sulfide Tailings

Waste Rock Areas
- South Waste Rock Area
- North Waste Rock Areas

Evaporation and Recycling Ponds
- North, Middle and South Lined Evaporation Ponds
- Finger Evaporation Ponds
- Unlined Evaporation Pond
- Lined Evaporation Pond (South, Middle and North)
- Pumpback Evaporation Pond
- Process Solution Recycling Ponds

Leach Pads
- Phase I Heap Leach Pad
- Phase II Heap Leach Pad
- VLT Heap Leach Pad
- Slot Heap Leach Pad

Process Areas
- Buildings
- Shops
- Fuel Storage Areas
- Ponds and other structures

Arimetco Electrowinning Facilities
- Electro-winning Plant
- Ponds and other structures
- Pipelines, ditches and other conveyances

Ancillary Mine Units
- Landfills
- Sewage Treatment Ponds
- Pipelines, ditches and other conveyances

Groundwater conditions associated with the Process Areas are currently being investigated under a separate Work Plan.

1.3 Hydrogeologic Setting

This section describes the general hydrogeologic conditions in the area surrounding the Yerington Mine Site, based on the following previous studies:

- Huxel, C.J., Jr., 1969, *Water Resources and Development in Mason Valley, Lyon and Mineral Counties, Nevada, 1948-1965*, Nevada Division of Water Resources Water Resources Bulletin No. 38 prepared in cooperation with the U.S. Geological Survey (this is a comprehensive hydrologic study of the Mason Valley area including water budgets and effects of agriculture on surface and groundwater quality and quantity).
- Seitz, Harold, Van Denburgh, A.S. and La Camera, Richard J., 1982, *Ground Water Quality Downgradient from Copper Ore Milling Wastes at Weed Heights, Lyon County, Nevada*, U.S. Geological Survey Open File Report 80-1217 (this study presents hydrologic and geochemical data on the effects of mining on groundwater quality from a number of monitor wells, most of which are no longer operational).
- Proffett, J.M., Jr., and Dilles, J.H., 1984, *Geologic Map of the Yerington District, Nevada*, Nevada Bureau of Mines and Geology, Map 77.
- Dalton, Dennis, 1999, *Arimetco Yerington Mine and Process Facility Site Assessment of Groundwater Quality*, consultant report prepared for Arimetco, Inc. for submittal to NDEP (interpretations of data presented in this report allege that potential impacts from Arimetco operations could not be distinguished from pre-existing impacts from Anaconda operations).
- Piedmont Engineering, 2001, *Yerington Shallow Aquifer Data Evaluation Report*, consultant prepared for ARCO, March 20, 2001 (interpretations of data presented in this report support specific working hypotheses to be verified.
- Applied Hydrology Associates, 1983, *Evaluation of Water Quality and Solids Leaching Data,* consultant report prepared for Anaconda Minerals Company, May 25, 1983 (interpretations of groundwater data are compared to the Seitz et. al. report; this report includes surface water and solids leaching data in addition to groundwater sampling).
- Applied Hydrology Associates, *Annual Monitoring and Operation Summary: Pumpback Well System, Yerington Nevada,* annual consultant reports prepared for Atlantic Richfield Company provides groundwater elevation and water quality data for the pumpback and associated monitor wells; also includes pumping rates and time-concentration plots for select constituents; this report helps to interpret the effectiveness of the pumpback well system in limiting down-gradient migration of impacted groundwater).

The Yerington Mine site is located on the west side of Mason Valley, a structural basin surrounded by the mountain ranges described above. The area is typical of basin-and-range topography. The mountain blocks are primarily composed of granitic, metamorphic and volcanic rocks with minor amounts of semi-consolidated to unconsolidated alluvial fan deposits. The

Singatse Range has been subject to metals mineralization, as evidenced by the large copper porphyry ore deposit at the Yerington Mine. Proffett and Dilles (1984) published a geologic map of the Yerington District that describes these features.

Unconsolidated alluvial deposits derived by erosion of the uplifted mountain block of the Singatse Range and alluvial materials deposited by the Walker River fill the structural basin occupied by Mason Valley in the vicinity of the mine site. These unconsolidated deposits, collectively called the valley-fill deposits by Huxel (1969), comprise four geologic units: younger alluvium (including the lacustrine deposits of Lake Lahontan), younger fan deposits, older alluvium and older fan deposits. Lake Lahontan lacustrine deposits appear to have been removed and reworked by the Walker River as it meandered back and forth across the valley Huxel (1969). Huxel estimated that Pleistocene Lake Lahontan in Mason Valley persisted for a relatively short time, and was less than 60 feet deep.

Seitz et. al. (1982) described the geologic setting of the area around the mine site based on existing information and the sub-surface information obtained through the drilling of test (i.e., monitor wells) north of the site by the U.S. Geological Survey in 1978. Alluvial fan deposits along the west margin of the valley and stream- and lake-deposited materials on the valley floor underlie the tailings and evaporation ponds.

Atlantic Richfield installed two shallow monitor wells (MW-2002-1 and MW-2002-2) in the area north and northwest of the mine site in June 2002. These wells were drilled with a core rig to collect detailed lithologic information from the shallow alluvial aquifer. Core samples generally consisted of a relatively uniform mix of fine-grained sand, silt and clay size fractions with little internal structure (i.e., bedding, laminations, etc.). The exception to the homogeneous character of the core samples occurred immediately above and at the depth where groundwater was intersected in one of the boreholes. At this horizon, fine clay laminations with minor folding or "slump" features were observed. Samples just above the top of the water table in both monitor well boreholes generally contained higher clay contents than those below.

SECTION 2.0
DATA QUALITY OBJECTIVES

The Data Quality Objectives (DQOs) for the initial evaluation of groundwater conditions presented in this Work Plan include the collection of appropriate data to support a future assessment of: 1) ecological and human health risks associated with mine-related groundwater that may have migrated off-site, and the potential for additional constituents of concern (COCs) to migrate to potential down-gradient receptors; and 2) management alternatives for limiting or preventing continued flow of mine-related groundwater flow to potential down-gradient receptors. In order to ensure that hydrogeologic and chemical data of sufficient quality and quantity are collected during the field activities described in this Work Plan, the following seven-step DQO process is presented:

- Step 1. State the Problem – Describe the problem and identify the resources available to resolve the problem;
- Step 2. Identify the Decision – Identify the questions that the study would attempt to answer;
- Step 3. Inputs to the Decision – Identify the information needed to support the decision and the measurements that need to be taken to resolve the decision statement;
- Step 4. Define the Boundaries of the Study – Specify the spatial and temporal aspects of the environmental media that the data must represent to support the decision;
- Step 5. Develop a Decision Rule – Develop unambiguous "If...then" statements that define the conditions that would trigger one of the alternative actions;
- Step 6. Specify the Limits on Decision Factors – Specify the acceptable limits on decision errors, which are used to establish performance goals for limiting uncertainty in the data; and
- Step 7 Optimize the Design for Obtaining Data – Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs.

The problem statement (Step 1) is as follows: "Groundwater conditions in the area of the Yerington Mine Site, including the areas west and north of the mine site with domestic wells uranium concentrations that exceed the MCL, are not completely known, and available information is inconclusive with respect to the source, transport pathways and fate of COCs in groundwater that may pose a risk to human health and the environment".

Step 2 of the DQO process (Identify the Decision) asks the key question(s) that this Work Plan attempts to address: "What initial borehole characterization, monitor well installation, sampling and analytical activities for selected locations around the Yerington Mine Site would: 1) improve understanding of the conceptual hydrogeologic model of the groundwater flow system at the site; 2) support an evaluation of the potential risk to the environment and human health; and 3) support the development and evaluation of groundwater management alternatives and ties at the groundwater protection goals?" The criteria necessary to determine if the proposed initial characterization activities would answer this question include, but may not be limited to:

- Adequacy of collected data to initially document the fate and transport of COCs in the groundwater flow systems associated with the Site at present, and COCs that may be sourced from surface mine units in the future;
- Adequacy of collected data to initially define "background" or "ambient" chemical concentrations in groundwater hydrologically up-gradient of the mine;
- Adequacy of collected data to initially document the efficiency of the existing pumpback well system to capture COCs that may be migrating to possible receptors located down-gradient of the Site; and
- Adequacy of collected data to initially document the effects of agricultural activities at the northern margin of the Site on ground water flow and solute transport.

Step 3 of the DQO process (Identify the Inputs to the Decision) identifies the kind of initial groundwater information that is needed to address the question posed under Step 2. This information would include:

- Three-dimensional lithologic and geochemical information, including background conditions, for the alluvial aquifer that supplies drinking water to domestic wells located north and west of the mine site;
- Groundwater elevation and groundwater quality data obtained through measurements and sampling of a three-dimensional array of groundwater monitor wells in the alluvial aquifer located north and west of the mine site;
- The response in selected portions of the alluvial aquifer to agricultural pumping and irrigation practices; and
- Groundwater elevation data in properly constructed piezometers associated with selected pumpback wells to assess the effectiveness of the pumpback well system in limiting the off-site migration of mine-related groundwater.

Step 4 of the DQO process (Define the Boundaries of the Study) defines the spatial and temporal aspects of the field monitoring, sampling and analytical activities proposed in this Work Plan. The area for the initial groundwater investigations described in this Work Plan is shown in Figure 2. The time frame for conducting the initial field activities described in this Work Plan would be March through September 2005. Monitor well installations would be completed in two steps as part of this Work Plan: 1) the first step would be in conjunction with the drilling of the stratigraphic boreholes; and 2) the second step would be performed after groundwater quality data is received from the analytical laboratory following depth-specific sampling in the boreholes. A Data Summary Report would be available within three months of receiving all data from the analytical laboratory, including groundwater sample results from "second-step" monitor wells. This temporal framework for the proposed groundwater investigations is dependent upon Atlantic Richfield receiving timely approval of this Work Plan, and permission to drill the boreholes from various land owners.

The initial groundwater investigations described in this Work Plan would be the first phase of a phased groundwater investigation program. Subsequent phases would be developed after the results presented in the Data Summary Report are reviewed by the EPA and Atlantic Richfield.

Step 5 of the DQO process (Develop a Decision Rule) determines if the proposed data collection activities would be of sufficient quantity and quality to satisfy the DQOs. Given that EPA hydrogeologists participated in the development of this Work Plan, Atlantic Richfield anticipates that the field data and analytical results would achieve data adequacy standards.

Step 6 of the DQO process (Specify the Limits on Decision Errors) would be based on measurement errors, rather than sampling errors, given that measurement errors would likely be the primary factors affecting any decision error. Laboratory-validated data would be required to limit measurement errors. Sampling errors would be limited, to the extent practicable, by following the procedures described in this Work Plan and in the Quality Assurance Project Plan (Brown and Caldwell, 2003b), along with EPA guidelines.

Step 7 of the DQO process (Optimize the Design for Obtaining Data) has been accomplished through EPA involvement in the development of this Work Plan. Atlantic Richfield anticipates that the initial groundwater investigations described in this Work Plan would result in subsequent groundwater investigation phases that, because of this iterative approach, would provide the most resource-effective sampling and analysis design.

The DQOs listed above and the associated field and laboratory activities presented in this Work Plan represent an initial phase of groundwater investigations associated with the Yerington Mine Site. Subsequent to the activities described in this Work Plan, Atlantic Richfield anticipates that additional groundwater investigation activities would be conducted including, but not limited to:

- Geophysical logging of a select number of monitor wells constructed in the deep zone of the alluvial aquifer to determine the effectiveness of in-casing techniques for implementation at other deep installations.
- Aquifer testing associated with the irrigation supply well and, potentially, other locations north of the mine site.
- Geotechnical characterization of selected borehole materials, pending further discussion with the Yerington Technical Work Group.
- Additional stratigraphic borehole drilling and monitor well construction, and additional piezometer construction as required.

SECTION 3.0
WORK PLAN

This Work Plan describes initial groundwater investigation activities designed to achieve the DQOs presented in Section 2.0. Implementation of this Work Plan would provide: 1) stratigraphic, aquifer material characteristics and groundwater quality data that would supplement existing site monitor well and domestic well data; 2) a three-dimensional view of groundwater conditions north of the mine site; 3) groundwater flow information; and 4) the basis to conduct subsequent investigations. Subsequent investigations would include a detailed assessment of the effects of irrigation practices on groundwater flow and quality, aquifer testing, additional monitor well installations, and a characterization of natural background populations of groundwater chemistry corresponding to the complexity of the hydrogeologic setting and groundwater flow system. The activities to be performed during the initial investigations, described in this Work Plan, include:

- Borehole drilling and stratigraphic logging;
- Depth-discrete groundwater sampling and analysis;
- Monitor well design and installation;
- Monitor well development and surveying;
- Groundwater sampling and analysis; and
- Piezometer and data logger installation.

Borehole drilling would be conducted using a Water Development Corporation (WDC) sonic core drilling rig to obtain a continuous, relatively undisturbed core of the alluvium for stratigraphic logging. The proposed total depths below ground surface (bgs) for the stratigraphic boreholes are described below and would be consistent with, and representative of, nearby domestic wells. At each borehole location, depth-specific groundwater samples would be collected for the measurement of field parameters and the submittal to an analytical laboratory for selected chemical analyses.

A groundwater monitor well would be constructed in each of the stratigraphic boreholes. The 20-foot screen for the first groundwater monitor well would be constructed at the deepest interval designated in the borehole, based on the collection of field data described below. Subsequently, one or two additional (i.e., "second-step") monitor wells would be constructed immediately adjacent to the first monitor well (i.e., within 20 feet). The monitor well designs would be based on: 1) an evaluation of the stratigraphic information encountered during drilling; 2) the depth-specific field parameter data; and 3) the screen intervals of nearby domestic wells, including those with elevated uranium concentrations. In addition, designs of the "second-step" wells would be based on the results of laboratory analytical results from the depth-specific samples.

Once constructed, monitor wells would be developed and surveyed. After development, groundwater samples would be collected from the monitor wells for laboratory analysis, as described below. In addition to the stratigraphic borehole and monitor well installation program, a piezometer (i.e., observation well) would be installed adjacent to pumpback well PW-3 and a second piezometer adjacent to pumpback well PW-10, to help evaluate the capture zones around pumpback wells with relatively high and low pumping rates. Piezometer construction would be consistent with the construction of the pumpback wells and would be located within five feet of each pumpback well. Data loggers would be installed in the piezometers to collect continuous groundwater elevation measurements in association with pumping rates and volumes.

Additional phased investigations of groundwater conditions are anticipated to be completed upon review of the data collected during the activities described in this Work Plan. All field and analytical results from the activities described in this Work Plan would be presented in a Data Summary Report.

3.1 Borehole Drilling and Data Collection

To provide a conceptual framework for the initial groundwater investigations proposed in this Work Plan, including the depth and locations of proposed stratigraphic boreholes, a north-south cross-section extending from the mine site to the Sunset Hills area was developed (Figure 3). The cross-section shows: 1) available lithologic information including the occurrence of subsurface clay horizons that may define shallow, intermediate and deep stratigraphic zones; 2)

proposed locations and depths for selected boreholes, and approximate monitor well screen intervals along the line of the section; and 3) domestic wells along the line of the section. Note that some existing domestic wells shown in Figure 3 are projected onto the plane of the cross-section. Figure 3 represents a preliminary conceptual hydrogeologic model for the alluvial aquifer immediately north of the mine site. Similar concepts, as schematically shown in Figure 4, have been presented in the *Conceptual Site Model for the Yerington Mine Site* (Brown and Caldwell, 2002b) and the *Draft Final Groundwater Conditions Work Plan* (Brown and Caldwell, 2003). In addition to the cross-section shown in Figure 3, domestic well construction data and associated groundwater quality were evaluated to design the proposed borehole and monitor well installation program.

Borehole Depths and Locations

Proposed depths for the stratigraphic boreholes generally range from 150 to 240 feet bgs, except where bedrock may be encountered at a more shallow depth. Proposed borehole depths are based on available well construction information for domestic wells, and the occurrence of uranium concentrations that exceed the MCL in the domestic wells. Tables 1 and 2 present construction information for selected domestic wells located in the Sunset Hills and the Luzier Lane/Locust Lane areas, respectively. Surface elevations for the domestic wells provided in Tables 1 and 2 were estimated using available aerial photography and topography for the mine site. Available well construction data were used in conjunction with these surface elevations to estimate the domestic well screen intervals. The proposed depths of the stratigraphic boreholes are presented in Table 3, based on the information presented in Tables 1 and 2.

Proposed borehole and monitor well construction locations are shown in Figures 2 and 5 as B/W designations (Figure 5 provides a more detailed view of the proposed wells located west and north of the mine site). These locations were selected in conjunction with EPA hydrogeologists to evaluate groundwater conditions: 1) in the areas of domestic wells with documented uranium concentrations that exceed the 30 ug/L MCL; 2) at two locations associated with agricultural operations immediately north of the mine site, including a site adjacent to an irrigation well that pumps significant volumes of groundwater on a seasonal basis; 3) at a location within the northern portion of the mine site approximately 750 north of existing site monitor well (MW-05)

with documented concentrations of uranium that exceed the MCL; and 4) potential areas that would represent background groundwater quality characteristics south of the mine site and west of the domestic wells of concern. Table 3 also summarizes the site selection criteria for the boreholes and wells.

In the Sunset Hills area, all of the domestic wells with screen intervals extend less than 180 feet bgs. As a result, groundwater from these domestic wells, including those with uranium concentrations above the MCL, is collected from elevations above 4,200 feet (above mean sea level) amsl. Therefore, stratigraphic boreholes B/W-4 and B/W-10 in the Sunset Hills area would be drilled to a depth of 200 feet bgs.

In the Locust Lane area, screen intervals in domestic wells DW-71 and DW-72 extend to 233 and 239 feet bgs, respectively, corresponding to elevations of 4,237 to 4,257 feet amsl for DW-71, and from 4,239 to 4,259 feet amsl for DW-72. Therefore, stratigraphic borehole B/W-6 would be drilled to approximately 240 feet bgs (approximately 4,236 feet amsl) or until it encounters bedrock, which ever is less..

Other domestic wells in these areas indicate that uranium concentrations above the 30 ug/L MCL also occur at elevations above 4,200 feet amsl. Therefore, stratigraphic boreholes B/W-2, B/W-3, B/W-5 and B/W-9 would be drilled to a depth of 150 feet bgs, given that ground surface elevations at these sites are all approximately 4,350 feet amsl. Because stratigraphic boreholes B/W-7 and B/W-8 are located adjacent to the Singatse Range, where ground surface elevations are slightly higher than the central portion of the Mason valley, these boreholes would be drilled to a depth of approximately 200 feet bgs, or until they encounter bedrock.

In the Luzier Lane area, irrigation well WDW019 extends to a depth of 365 feet bgs and has a 315-foot long screen interval. Groundwater pumped from this well would likely represent yields from the shallow, intermediate and deep zones in the alluvial aquifer. Therefore, stratigraphic borehole B/W-1 would be drilled to a depth of 200 feet bgs to ensure that the shallow, intermediate and deep zones are evaluated.

Borehole B/W-11, located on the mine site, would be drilled to a depth of 200 feet bgs to evaluate groundwater quality throughout the stratigraphic sequence depicted in Figure 3, and the potential for COCs to vertically migrate to depth beneath the area of evaporation ponds. Boreholes B/W-12 and 13, generally located south of the mine site to assess potential background water quality, would be drilled to a depth between 150 and 200 feet bgs. This uncertainty is associated with limited groundwater and depth-to-bedrock information in this area. If bedrock is encountered at depths less than 150 feet bgs in these areas, the boreholes would be terminated at the alluvium-bedrock contact and the monitor wells would be constructed above the contact.

Drilling and Sampling Methods

Stratigraphic boreholes would be advanced using the roto-sonic drilling technique, which employs simultaneous high frequency vibration and low speed rotational motion along with downward pressure to advance the core barrel. A 4-inch diameter, 5-foot long core barrel is first advanced five feet into the ground, and is followed by a 6-inch override casing drilled to the same depth as the core barrel cutting shoe. The core barrel is then removed and the 5-foot soil core is extruded into plastic sleeves. The core barrel is then sent back down into the hole where it is advanced another 5 feet followed again by the override casing. The outer casing prevents cross-contamination and formation mixing, and allows for controlled placement of temporary well screens and pumps for sampling, and down-hole instrumentation.

Upon collection, the soil core would be described using the American Society of Testing and Materials (ASTM; 1992) Standard D 2487-92 – Classification of Soils for Engineering Purposes (Unified Soil Classification System). Core samples would be archived at the mine site in plastic containers to preserve their soil texture.

Groundwater samples would be collected from each borehole location to: 1) obtain depth-specific chemical data (field data for the initial deep monitor well and laboratory analytical data for co-located shallow and or intermediate monitor wells) that, in conjunction with lithologic logging, would assist in the design of the monitor well screen intervals; and 2) obtain laboratory analytical data to evaluate the vertical distribution of groundwater chemistry and, if present,

COCs in groundwater. Depth-specific sampling would: 1) provide a three-dimensional picture of groundwater conditions north of the mine site; 2) improve the site conceptual hydrogeochemical model; and 3) assist in the evaluation of spatial heterogeneity and contaminant transport parameters in the groundwater flow system.

At least 10 depth-specific ground water samples would be collected per borehole (the maximum interval between groundwater screening samples would be 20 feet). In addition to nominal 15-foot or 20-foot intervals in each borehole, sampling intervals would be based on lithologic information collected during drilling and the construction of nearby domestic wells, as follows:

- Within the first five feet immediately beneath the first encountered water table
- At the bottom of the shallow (hydrostratigraphic) zone above the first clay horizon
- At the first transmissive zone immediately below the first shallow clay horizon
- In the middle of the intermediate (hydrostratigraphic) zone, at elevations consistent with the screen intervals of nearby domestic wells and/or where transmissive zones are encountered
- At the bottom of the intermediate (hydrostratigraphic) zone
- At the first transmissive zone immediately below the deep clay
- At elevations consistent with the screen intervals of nearby domestic wells

A detailed description of groundwater sampling procedures using the roto-sonic core drill is provided below, and a schematic illustration of the casing/packer/pump assembly is presented in Appendix A. The alluvial formation would be cored using the 6-inch casing and the 4-inch sonic core barrel, and a 6-inch temporary casing would be advanced to the bottom of the cored interval, and a core sample would be obtained from the subjacent interval. At the designated interval in the aquifer, based on lithologic or other information, the 4-inch sonic core barrel would be advanced beyond the 6-inch temporary casing and the soil sample would be retrieved. A 3-inch diameter stainless steel screen and 3-inch diameter riser casing would be vibrated into the cored section of the borehole allowing the formation to collapse around the screen. A 3-inch by 6-inch K-packer would separate and center the 6-inch sonic casing and 3-inch riser.

A submersible pump would then be lowered into the riser and set in the screen. An inflatable packer is located above the pump on the pump drop/column pipe. The packer would be inflated, isolating the screen section and the depth-specific groundwater sample would be obtained after the appropriate volume of groundwater is purged. The packer would then be deflated and the pump removed from the 3-inch screen and riser. The screen and the 3-inch riser is vibrated from the formation. Temporary casing would then be advanced to the bottom of the sampled interval, and the operation would be repeated at the next interval to be sampled.

Groundwater samples would be collected using a peristaltic pump and dedicated lengths of small diameter polyethylene tubing for each discrete sampling interval. Subsequent to collecting the groundwater sample, the stainless steel screen would be decontaminated in accordance with the procedures specified in the QAPP (Brown and Caldwell, 2003), consistent with EPA guidelines (EPA, 1996 and 1992).

The parameter suite for the depth-specific groundwater screening samples would consist of: 1) field measurements of pH, conductivity, temperature, DO, oxidation-reduction potential (ORP), iron (un-speciated, or "total"), ferrous iron (Fe^{2+}), sulfate, nitrate and alkalinity; and 2) laboratory analysis of uranium (filtered and unfiltered), arsenic (filtered and unfiltered) and total organic carbon. These parameters and laboratory analyses are summarized in Table 4. Filtering would be performed using a 0.45 micron filter. Procedures for performing field analysis of total iron, ferrous iron, sulfate, nitrate and alkalinity are presented in Appendix B. A more detailed description of the laboratory analyses to be conducted as part of this Work Plan is described below.

3.2 Monitor Well and Piezometer Construction

As described above, screen intervals for the deep of monitor well installation in each borehole (termed "first-step" monitor wells in this Work Plan) would be based on: 1) lithologic information obtained during drilling; 2) field parameter measurements and analyses of the depth-specific groundwater samples obtained during drilling; and 3) available construction details for nearby domestic wells. Designs for "second-step" monitor wells to be constructed in the shallow and/or intermediate portions of the alluvial aquifer would be developed in consultation with EPA

hydrogeologists, and would also be based on laboratory analytical results from the depth-specific groundwater samples collected during borehole drilling.

Lithologic information to be used in designing the monitor wells would include alluvial materials grain size, degree of sorting, visually estimated aquifer properties (i.e., transmissivity) and presence or absence of clay horizons that may serve as aquitards. Screen intervals would also be based on: 1) field observations of groundwater inflow rates during depth-specific sampling; and 2) depth-specific occurrences of field parameter measurements (and laboratory analyses for "second-step" monitor wells) that indicate the influence of mine-related groundwater (e.g., field measurements of specific conductance and pH, elevated sulfate and/or iron concentrations) or the presence of COCs that exceed MCLs. Nitrate and alkalinity may help identify the influence of irrigation practices on groundwater chemistry.

Construction Methods

All monitor wells would be constructed to allow for the collection of groundwater elevation measurements and groundwater quality samples. Monitor wells would be constructed with a nominal 15-foot long 6-inch diameter steel surface casing, and 2-inch diameter schedule 40 PVC tubing as the blank (i.e., not screened) portion of the well. Approximately three feet of the steel surface casing would stick up above the ground surface to protect the plastic tubing of the monitor well.

A 20-foot, 0.020-inch slotted screen constructed of schedule 40 PVC would be installed at the design interval. A 2-inch flush-threaded PVC end cap would be placed at the bottom of the screened interval. Where necessary, the borehole beneath the screen and bottom cap would be filled with bentonite grout (nominally 0.375-inch pellets).

A filter pack consisting of 10/20 silica sand would be placed against the well screen and would extend approximately 3 feet above the top of the screen interval (i.e., 23 feet of filter pack placed in the annulus). A 6-inch layer of finer filter-pack sand material would be placed on top of the coarser filter pack to limit bentonite intrusion. Bentonite would be used to fill the annular space

above the fine filter sand to approximately 10 feet bgs. A 10-foot cement seal would then be placed in the annular space to the surface.

A locking 6-inch diameter well monument would be installed with a stick-up of approximately 3 feet above ground surface. A nominal 6-inch thick, 2-foot by 2-foot concrete slab would be placed around the surface casing. The well monument would contain the name of the monitor well with designations for shallow, intermediate or deep completions (e.g., B/W-10S and B/W-4D).

After the bentonite grout and cement surface seal has cured, each monitor well would be developed to remove fine-grained material from the well and to improve the hydraulic connection to the screened portion of the alluvial aquifer. Development procedures would include surging the well and periodically pumping or bailing of fine grained material until the turbidity of the discharge water is less than or equal to10 nephelometric turbidity units (NTUs) or has stabilized (i.e., varies less than +/- 10% over three successive casing volumes.

A Nevada-registered surveyor would be employed to survey the horizontal and vertical locations of each new monitor well, including the ground surface and top-of-casing elevations. The reference measurement point for taking depth-to-water measurements would be permanently marked on the top of the well casing, and would be surveyed within +/-0.01 foot in relation to mean sea level and to Nevada State Plane West Zone coordinates (NAD 27).

Sampling of Monitor Wells

Prior to water quality sampling, groundwater level measurements would be recorded for the new monitor wells. An electronic water level probe would be used to measure the depth to groundwater in each well to the nearest 0.01 foot from the surveyed points on the well casings (if measured prior to surveying, the measurement point would be clearly marked on the casing so that the reference measurement point can be correctly identified later by the surveyor). The depth-to-groundwater measurements would be recorded in a field logbook per the QAPP.

Prior to sampling, the groundwater quality monitoring probes/meters including pH, conductivity, temperature, DO and ORP would be calibrated daily in accordance with manufacturer's instructions. At a minimum, two-point calibrations would be conducted for pH and conductivity. The dissolved oxygen probe would be checked against a zero-dissolved oxygen solution. In addition, the dissolved oxygen calibration would be corrected for local barometric pressure and elevation. Calibration results would be recorded in a field logbook according to the QAPP.

The parameter suite for the groundwater samples would consist of: 1) field measurements of pH, conductivity, temperature, DO and ORP; and 2) laboratory analysis of the constituents listed in Table 5. After the initial sampling activities described in this Work Plan, the new monitor wells would then be included in the quarterly monitoring program performed by Atlantic Richfield (note that the analytical parameters presented in Table 5 may be modified pending further discussion with EPA). Groundwater samples would be collected from the newly installed monitor wells using low-flow (minimal drawdown) sampling procedures that are consistent with EPA guidance (EPA, 1996 and 2002), per the following procedures:

- The pumping system would be prepared for operation by connecting the tubing to the in-line water quality meter and lowering the pump and tubing into the well, with the intake positioned at the approximate middle of the well screen.
- Commence well purging by low-flow pumping from the well at a flow rate not to exceed 500 milliliters per minute (ml/min). Initially a flow rate between 200 and 500 ml/min would be used. Efforts would be made to minimize generation of air bubbles in the sampling tubing by either increasing the flow rate as appropriate, or restricting the flow by clamping the tube. The purge rate would be recorded in the field logbook or field sampling form.
- Ideally, drawdown in the well should not exceed 0.3 feet. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump to help allow parameter stabilization.
- During purging, field parameters would be monitored and recorded including pH, conductivity, temperature, ORP and DO at time intervals sufficient to evacuate the volume of the flow-through cell, which would be calculated by dividing the volume of the flow-through cell by the pumping rate.
- Well sampling can commence after equilibration of water quality parameters. Equilibrated trends are generally obvious and usually follow either an exponential decay or asymptotic trend during purging.
- If the indicator field parameters have not stabilized after one hour of purging, then discontinue purging and collect the groundwater samples.

Equilibration is defined as three consecutive water quality parameter readings that meet the following EPA guidelines:

- Temperature +/- 3%
- pH +/- 0.1 Standard Units
- Conductivity +/- 3%
- ORP +/- 10 mV
- DO +/- 10%
- Turbidity +/- 10% when turbidity exceeds 10 NTUs.

Piezometers to be installed adjacent to pumpback wells PW-3 and PW-10 would be constructed in a similar fashion to that of the monitor wells, and their screen intervals would be consistent with the construction of the pumpback wells. No groundwater samples would be obtained from the piezometers. Continuous groundwater elevation measurements from the two piezometers would be obtained using a pressure transducer and data logger. A description of the Global Water WL 15 logger, proposed for use in the piezometers, is included in Appendix B.

Sample Handling, Transport and Documentation

Preparation of groundwater samples in the field for transport to the laboratory (including handling, labeling, packaging, documentation, shipment preparation and custodial quality control) would be conducted in accordance with the QAPP (Brown and Caldwell, 2003b). After field parameters have stabilized, a groundwater sample would be collected from the submersible pump installed in the well. The sample would be decanted into an appropriate sample container depending on the required analysis. Both filtered samples for dissolved constituents and unfiltered samples for total constituents would be each collected in 500-milliliter (mL) bottles. Samples for dissolved metals analysis would be filtered through a 0.45-micron filter.

Immediately after collecting the groundwater sample, nitric acid would be added to each dissolved or total metals sample container until the field pH measurement of the sample is less than 2 standard units. Non-metals samples would be collected in 1,000-mL bottles with no acid

preservation. Immediately following collection, samples would be placed into an insulated cooler chilled with ice to an approximate temperature of four degrees centigrade. The samples would then be transported to the analytical laboratory via overnight mail or personal delivery. Sample containers, preservation methods, and filtering methods are summarized below.

Decontamination of purging equipment would be performed between the sampling of each monitor well by: 1) submerging and scrubbing the outside of the pump and associated hosing in an Alconox detergent bath; and 2) twice rinsing the inside of the pump in de-ionized water. At least five gallons of Alconox detergent solution followed by five gallons of de-ionized water would be used to rinse the internal portion of the pump.

Sample Identification and Preservation

Sample labels would be completed with a permanent marker and attached to each sample container prior to ground water collection. Strict attention would be given to ensure that each sample label corresponds to the collection sequence number marked on the bottle prior to sample collection. The labels would include the following information:

- Sample identification and type
- Sample date and time
- Sample preparation and preservative
- Analyses to be performed
- Person who collected sample

Each sample would be tracked according to a unique sample field identification number assigned when the sample would be collected. This field identification number consists of three parts:

- Sampling event sequence number
- Sampling location
- Collection sequence number

Blanks and duplicate samples for quality assurance would be labeled in the same fashion, with no obvious indication of their sample location or quality. Procedures for maximum holding times, storage conditions, and preservative method are presented below:

Sample Control Procedures

Parameter	Amount for Analysis	Container	Filtering	Maximum Hold Time	Storage Conditions	Preservatives
TDS	1,000 mL	1,000 mL HDPE	None	7 days	4°C	none
Sulfate	500 mL	1,000 mL HDPE	None	28 days	4°C	none
Nitrate	100 mL	1,000 mL HDPE	None	48 hours	4°C	H_2SO_4 to pH<2
Total Metals	Varies per metal	500 mL HDPE	None	6 months*	4°C	HNO_3 to pH<2
Dissolved Metals	Varies per metal	500 mL HDPE	0.45 µm	6 months*	4°C	HNO_3 to pH<2
Acidity/ Alkalinity	100/200 mL	500 mL HDPE	None	14 days	4°C	none

TDS= Total Dissolved Solids HDPE= High-density polyethylene ml=milliliters
HNO_3= Nitric acid H_sSO_i= Sulfuric Acid

The following sample preservation methods would be followed for collected groundwater samples:

- If the sample is to be analyzed for dissolved metals, filter sample through a 0.45-micron filter using an inline filter immediately after sample collection. After filtering, add nitric acid to the sample until the pH is less than 2.
- If the sample is to be analyzed for total metals, do not filter. Add nitric acid to the collected sample until the pH is less than 2.
- Check the pH by pouring a small amount of sample into the bottle cap and checking the pH with pH paper.
- Discard the liquid in the cap after checking the pH.
- Replace the cap, place the sample container in a sealed zip-loc plastic bag, and cool the sample to 4°C by immediately placing it in an insulated chest with containerized ice.
- Indicate on the sample label what the requested analysis is (e.g., dissolved or total).
- Observe the maximum holding times and storage conditions for all collected water samples.

Sample Handling and Transport

The QA objectives for the sample-handling portion of the field activities are to verify that decontamination, packaging and shipping are not introducing variables into the sampling chain which could render the validity of the samples questionable. In order to fulfill these QA objectives, blank and duplicate QC samples would be used as described below. Duplicate samples would be collected at a frequency of one in ten samples for each analysis. Duplicate samples would be collected by filling the bottles for each analysis at the same time the original sample is collected. Each sample from a duplicate set would have a unique sample number labeled in accordance with the identification protocol, and the duplicates would be sent "blind" to the lab (i.e., no special labeling of the duplicate would be provided).

A field sample would be designated as the "lab QC sample" at a frequency of 1 per 20 samples (including blanks and duplicates) for all parameters. The lab QC sample is the sample the laboratory would use for its internal quality control analyses. The lab QC sample for water analyses would be a double volume sample. The lab QC sample would be a sample that is representative of other contaminated samples. The sample containers and paperwork would be clearly labeled "Lab QC Sample".

A blank sample would be collected by pouring the blank water directly into the sample bottles at one of the sample locations. De-ionized water would be used for collecting blank water samples. Field blanks would be labeled in the same manner as other samples and would be sent "blind" to the lab, with no special indication of the nature of the sample.

Chain-of-custody protocol would be followed throughout the transport process. Each chain-of-custody would contain the following information:

- Project name
- Sampler's name and signature
- Sample identification
- Date and time of sample collection
- Sample matrix
- Number and volume of sample containers

- Analyses requested
- Filtration completed or required
- Method of shipment

The following sample packaging and shipment procedures would be followed for collected water samples to ensure that samples are intact when they arrive at the designated laboratory:

1. Place a custody seal over each container, and place each container in a zip-loc plastic bag and seal the plastic bag shut.
2. Place the sealed containers in the insulated ice chest.
3. If required, fill empty spaces in the ice chest with either ice, pelaspan (styrofoam popcorn), or bubble-pack wrap to minimize movement of the samples during shipment. Contained ice would be double bagged in zip-loc plastic bags to avoid water leakage.
4. Enclose the chain of custody form and other sample paperwork in a zip-loc plastic bag. If shipping the ice chest, tape the plastic bag to the inside of the ice chest lid. If self-transporting the ice chest, tape the plastic bag to the outside of the ice chest lid. Keep a copy of all paperwork.
5. Seal the ice chest shut with strapping tape and place two custody seals on the front of the cooler so that the custody seals extend from the lid to the main body of the ice chest. Place clear tape over each custody seal on the outside of the ice chest.
6. If shipping the ice chest, label it with "Fragile" and "This End Up" labels. Include a label on each cooler with the laboratory address and the return address.
7. Transport ice chests to the appropriate laboratory within 24 hours by hand-delivery or via express overnight delivery.

Laboratory Analyses and QA/QC

An EPA-certified laboratory would perform laboratory analyses. Criteria that are qualitative and quantitative indictors of laboratory data quality are precision, accuracy, representiveness, completeness and comparability, as described below:

- Precision is a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions (usually expressed in terms of the relative percent difference or standard deviation).
- Accuracy is the degree of agreement of a measurement with an accepted reference or true value. Usually expressed in terms of percent recovery.

- Representiveness refers to a sample or group of samples that reflects the characteristics of the media at the sampling point. It also includes how well the sampling point represents the actual parameter variations.
- Completeness describes the amount of valid data obtained from a series of measurements relative to the amount anticipated to achieve the DQOs for this Work Plan.
- Comparability expresses the confidence with which one data set can be compared to another. Data comparability can be ensured by reporting each data type in consistent units (e.g., all field measurements would be reported in consistent units and analytical methods would be similar or equivalent for all rounds of sampling). Comparability and representiveness are also ensured by the use of established field and laboratory procedures and their consistent application.

Documentation

Summary of field measurement and sampling activities would be recorded in a field notebook with integral bound pages, and entries would contain accurate and inclusive documentation of project activities in objective and factual language. Entries would be made using permanent waterproof ink, and erasures are not permitted. Errors would be single-lined out, should not be obscured, and initialed and dated. The person making the entries would sign at the beginning and the end of the day's entries, and a new page would be started for each day. The following entries would be made to the bound site logbook and/or filed log sheets:

- General descriptions of weather conditions
- Location of each sampling point
- Data and time of sample collection (field log sheets.)
- The type of blank collected and the method of collection
- Field measurements made, including the date and time of measurements
- Calibration of field instruments
- Reference to photographs taken
- Date and time of equipment decontamination
- Field observations and descriptions of problems encountered
- Duplicate sample location

3.3 Site Job Safety Analysis

A site-specific Job Safety Analysis (JSA) is presented in Appendix D. This JSA has been prepared in the context of the revised Health and Safety Plan (SHSP) for the Yerington Mine Site (Brown and Caldwell, 2004). The SHSP identifies, evaluates and prescribes control measures for health and safety hazards, including radiological hazards, and describes emergency response procedures for the site. SHSP implementation and compliance would be the responsibility of Atlantic Richfield's contractor, with Atlantic Richfield taking an oversight and compliance assurance role.

Changes or updates would be the responsibility of the contractor with review by Atlantic Richfield Safety Representative Lorri Birkenbuel. Copies of the SHSP are located at the site, in Atlantic Richfield's Anaconda office, and in the contractor's office. The SHSP includes:

- Safety and health risk or hazard analysis;
- Employee training records;
- Personal protective equipment (PPE);
- Medical surveillance;
- Site control measures (including dust control);
- Decontamination procedures;
- Emergency response; and
- Spill containment program.

The SHSP includes a section for site characterization and analysis that would identify specific site hazards and aid in determining appropriate control procedures. Required information for site characterization and analysis includes:

- Description of the response activity or job tasks to be performed;
- Duration of the planned employee activity;
- Site topography and accessibility by air and roads;
- Safety and health hazards;
- Hazardous substance dispersion pathways; and
- Emergency response capabilities.

All contractors would receive applicable training, as outlined in 29CFR 1910.120(e) and as stated in the SHSP. Site-specific training would be covered at the briefing, with an initial site tour and review of site conditions and hazards. Records of pre-entry briefings would be attached to the SHSP. Project tasks and associated potential hazards are summarized below.

Project Tasks and Associated Potential Hazards, Yerington Mine Site	
Sequence of Basic Job Steps	**Potential Hazards**
Well/Piezometer installation: drilling rig mobilization and setup	▪ Traffic and pedestrian mishaps and resulting bodily injury. ▪ Drilling into underground utilities. ▪ Striking overhead lines or objects with drill mast. ▪ Physical hazards associated with handling and transferring fuel to machinery. These include ignition/explosion, dermal irritation, inhalation of fumes, accidental ingestion, and eye contact.
Well/Piezometer Installation: drilling activities	▪ Injury to hearing from noise. ▪ Inhalation hazards from dust from drilling activities. ▪ Physical injury from moving parts of machinery. ▪ Physical hazards to personnel on the ground in the vicinity of the heavy machinery.
Well/Piezometer Installation: construction	▪ Inhalation of silica sand, bentonite, or concrete dust. ▪ Eye injury or irritation from splashing ground water. ▪ Physical hazards associated with use of hand tools to tighten or loosen augers.
Surveying	▪ Traffic and pedestrian mishaps and resulting bodily injury. ▪ Lightning.
Collect Monitor Well Field Parameter Measurements	▪ Skin irritation from dermal or eye contact. ▪ Slipping or falling on wet ground surface.
Purge Monitor Wells	▪ Skin irritation from dermal or eye contact. ▪ Slipping or falling on wet ground surface.
Prepare sample bottles and dress in appropriate PPE.	▪ Burn or corrosion from acid spillage, if sample bottles do not have acid already in them.
Collect Ground Water Samples and Decontaminate Equipment	▪ Skin irritation from dermal or eye contact. ▪ Slipping or falling on wet ground surface.
Package and Transport Groundwater Samples to Laboratory	▪ Traffic and pedestrian mishaps and resulting bodily injury.
All Activities	▪ Slips, Trips, and Falls. ▪ Back, hand, or foot injuries during manual handling of materials. ▪ Heat exhaustion or stroke. ▪ Hypothermia or frostbite.
Unsafe conditions.	▪ All potential hazards.

Elements to be covered in site-specific training include: persons responsible for site-safety, site-specific safety and health hazards, use of PPE, work practices, engineering controls, major tasks, decontamination procedures and emergency response. Other required training, depending on the particular activity or level or involvement, must include OSHA 40-hour training and annual 8-hour refresher courses. Other training may include, but is not limited to, competent personnel training for excavations and confined space. Copies of site personnel OSHA certificates would be attached to the SHSP.

JSAs for this Work Plan incorporate individual tasks, the potential hazards or concerns associated with each task, and the proper clothing, equipment, and work approach for each task. Given that potential radiological hazards may exist both on and off the mine, the JSAs and the updated version of the SHSP addresses this concern. Copies of Training Certificates for all site personnel would be attached to the SHSP. Personnel would initially review the JSA forms at a pre-entry briefing.

SECTION 4.0
REFERENCES CITED

American Society of Testing and Materials (ASTM), 1992. Standard D 2487-92. Classification of Soils for Engineering Purposes (Unified Soil Classification System).

Applied Hydrology Associates, 1983, *Final Report: Evaluation of Water Quality and Solids Leaching Data Adjacent to the Weed Heights Operation near Yerington, Nevada.* Prepared for Anaconda Minerals Company.

Applied Hydrology Associates, *Annual Monitoring and Operation Summary Reports, Pumpback Well System, Yerington, Nevada.* Prepared for Atlantic Richfield Company.

Brown and Caldwell, 2002a, *Conceptual Site Model for the Yerington Mine Site.* Prepared for Atlantic Richfield Company.

Brown and Caldwell, 2002b, *Draft Quality Assurance Project Plan.* Prepared for Atlantic Richfield Company.

Brown and Caldwell, 2003, *Draft Final Groundwater Conditions Work Plan.* Prepared for Atlantic Richfield Company.

Brown and Caldwell, 2004, *Revised Site Health and Safety Plan for the Yerington Mine Site,* Prepared for Atlantic Richfield Company.

Dalton, Dennis, 1999, *Arimetco Yerington Mine and Process Facility Site Assessment of Groundwater Quality.* Report prepared for Arimetco, Inc.

Huxel, C.J., 1969, *Water Resources and Development in Mason Valley, Lyon and Mineral Counties, Nevada, 1948-65.* State of Nevada Department of Conservation and Natural Resources, Division of Water Resources, Water Resources Bulletin No. 38.

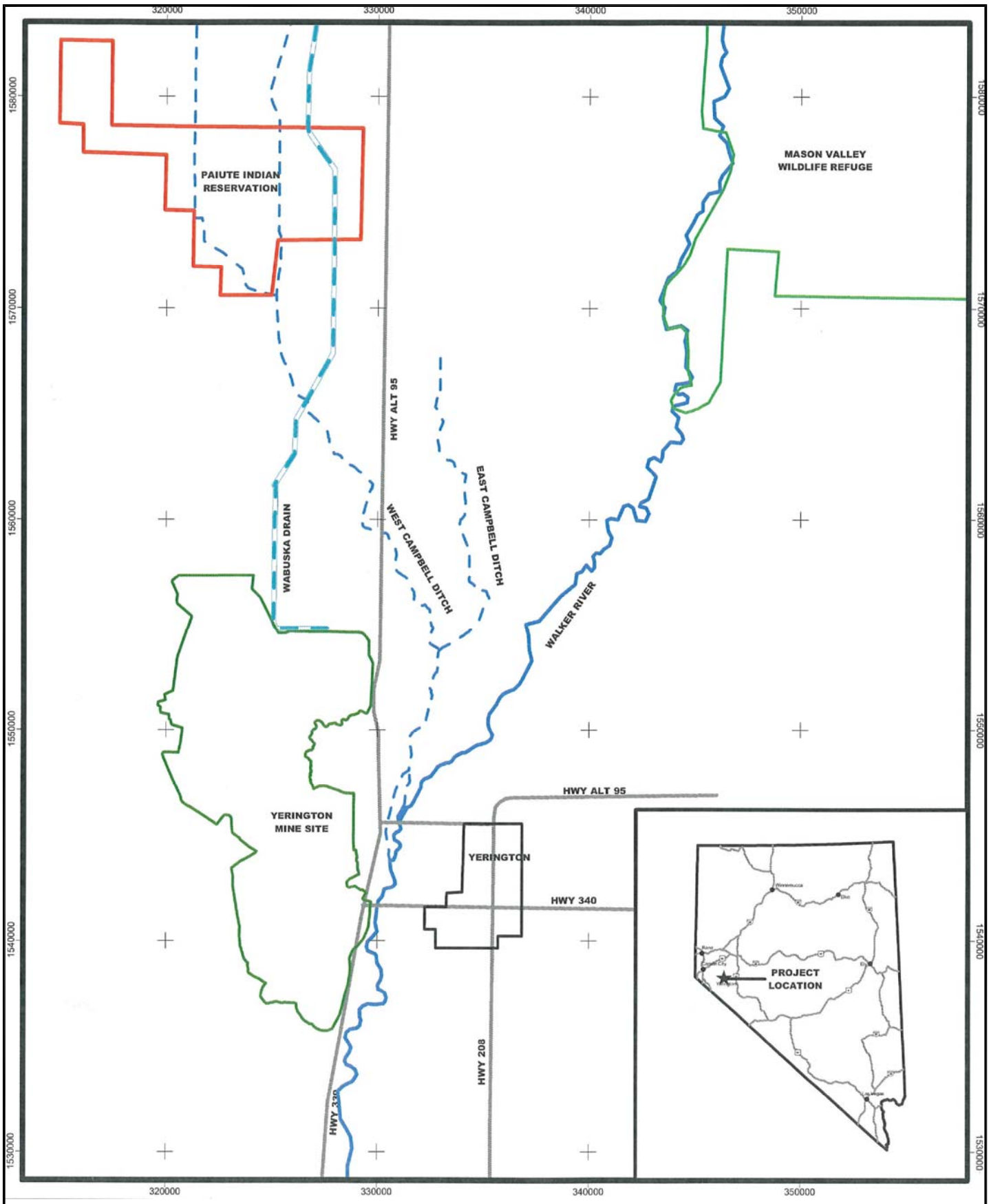
Proffett, J.M., Jr., and Dilles, J.H., 1984, *Geologic Map of the Yerington District, Nevada.* Nevada Bureau of Mines and Geology, Map 77.

Piedmont Engineering Inc., 2001, *Yerington Shallow Aquifer Data Evaluation Report.* Prepared for ARCO Environmental Remediation L.L.C.

Seitz, H.R., A.S. Van Denburgh, and La Camera, R.J., 1982, *Ground-Water Quality Downgradient from Copper-Ore Milling Wastes at Weed Heights, Lyon County, Nevada.* U.S. Geological Survey, Open-File Report 80-1217.

U.S. Environmental Protection Agency (EPA), 1996, *Ground Water Issue, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, by R. W. Puls and M.J. Barcelona. Office of Research and Development. EPA/540/S-95/504. April.

U.S. Environmental Protection Agency (EPA), 2002. *Ground-Water Sampling Guidelines for Superfund and RCRA Projejct Managers.* Ground Water Forum Issue Paper, by D. Yeskis and B. Zovala. Office of Solid Waste and Emergency Response. EPA 542-S-02-001. May.

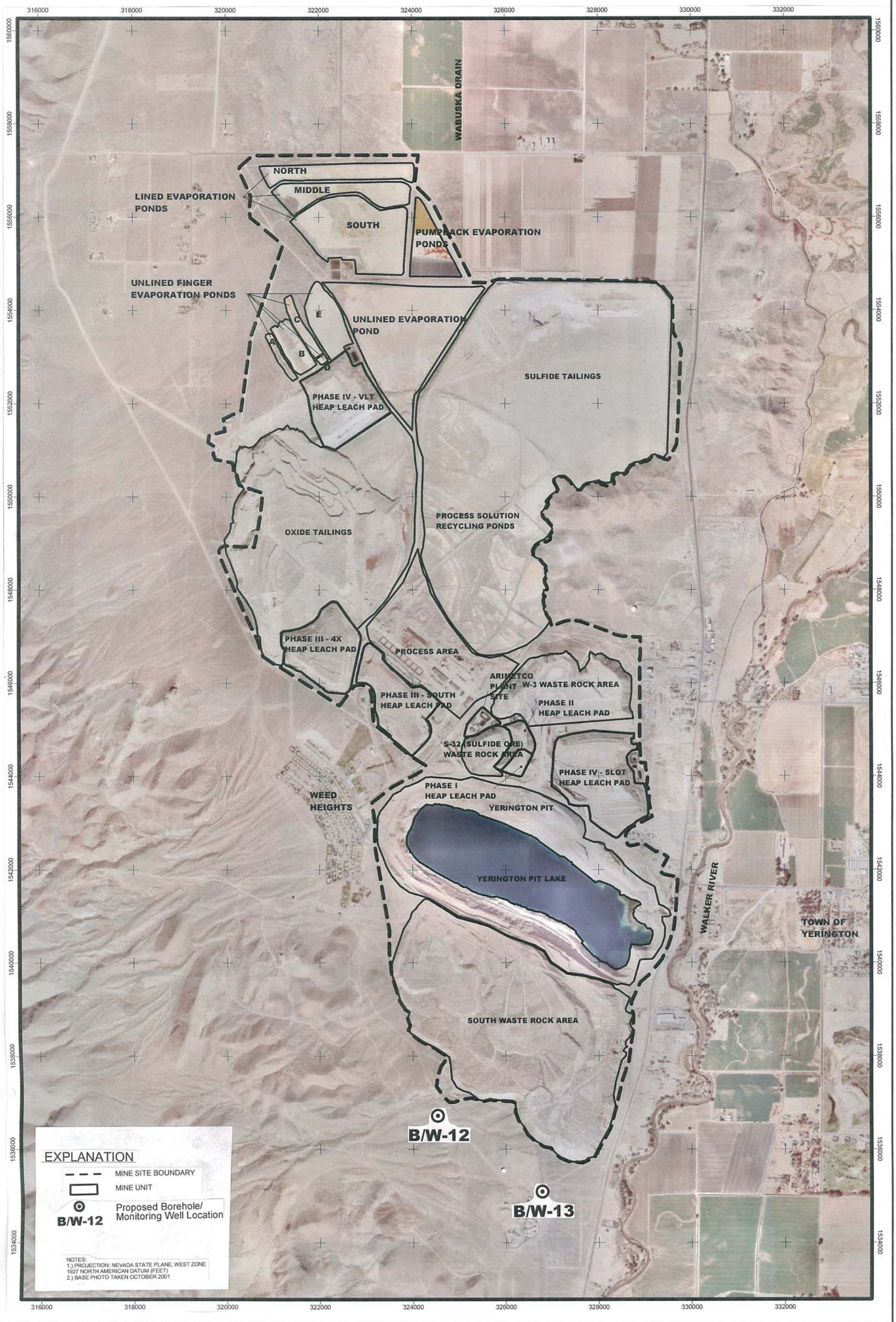


Notes:
Projection: Nevada State Plane, West Zone
1927 North American Datum (Feet)

DATE:	PROJECT NUMBER:	SCALE:		
Jan. 2005	21243	0 3000 6000 SCALE IN FEET	Atlantic Richfield Company	**Figure 1** **Site Location**

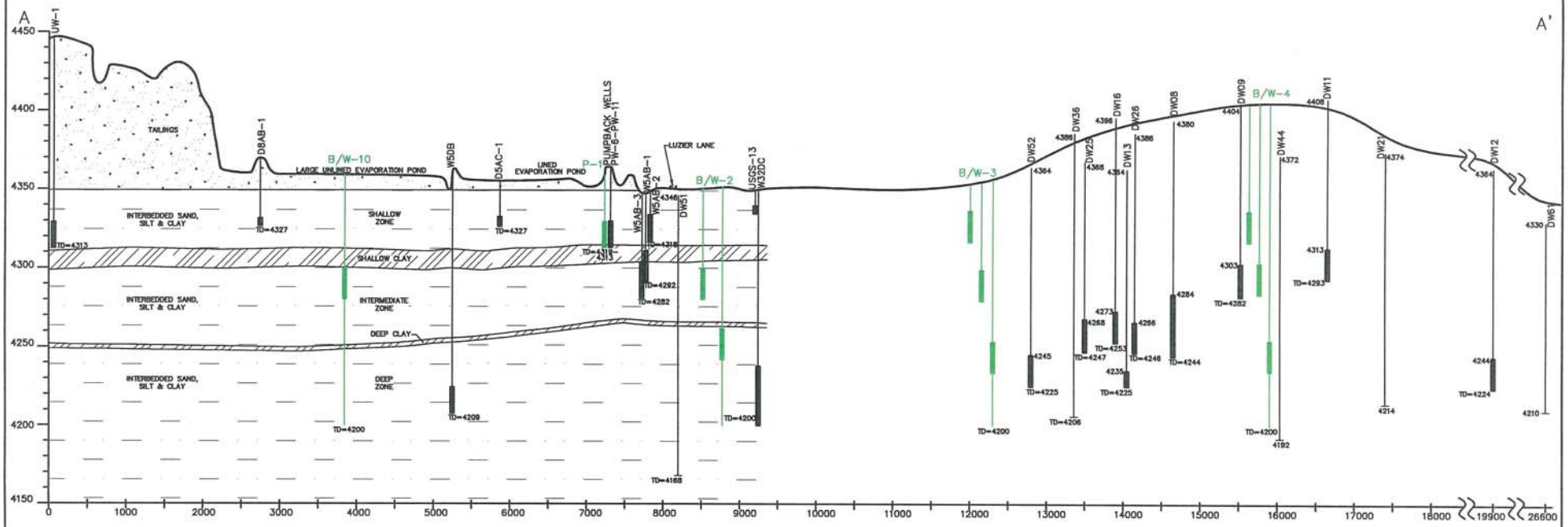
BROWN AND CALDWELL
Carson City, Nevada

Carson City Cad: P:\ARCO\21243\Groundwater Conditions\CAD\January 2005\F21243001.dwg (1=1) 01/13/2005 10:56:04 RJJ



DATE:	PROJECT NUMBER:	SCALE:		
Jan. 2005	21243	0 1000 2000 SCALE IN FEET	Atlantic Richfield Company	**Figure 2** **Surface Mine Units and Proposed Background Monitor Well Locations (South of Mine Site)**

BROWN AND CALDWELL
Carson City, Nevada



LEGEND

- TAILINGS
- CLAY
- INTERBEDDED SAND, SILT & CLAY

B/W-2 — WELL ID

APPROXIMATE SCREEN INTERVAL

APPROXIMATE DEPTH OF STRATIGRAPHIC BORING

NOTES:

1) DOMESTIC WELL LOCATIONS AND ELEVATIONS ARE APPROXIMATE. DOMESTIC WELL LOCATIONS WERE BASED ON GPS SURVEYING AND GROUND SURFACE ELEVATIONS WERE APPROXIMATED FROM AERIAL PHOTOGRAPHY OVERLAID ON TOPOGRAPHIC MAPS.

2) PROPOSED WELL LOCATIONS AND SCREEN INTERVALS ARE APPROXIMATE AND WILL BE MODIFIED BASED ON FIELD FINDINGS DURING DRILLING.

3) ONSITE CROSS SECTION DEVELOPED BY ATLANTIC RICHFIELD COMPANY; OFFSITE CROSS SECTION DEVELOPED BY SECOR.

0 600 1200

SCALE IN FEET

SECOR
14998 W. 6th Avenue, Suite 800
Golden, Colorado
(303) 278-7878

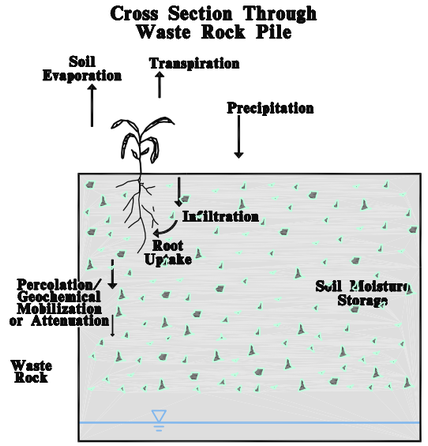
PREPARED FOR:
ATLANTIC RICHFIELD COMPANY
YERINGTON MINE SITE
YERINGTON, NEVADA

LITHOLOGIC CROSS SECTION FROM WELL UW-1 THROUGH DW61 SHOWING SELECT NEW MONITOR WELLS

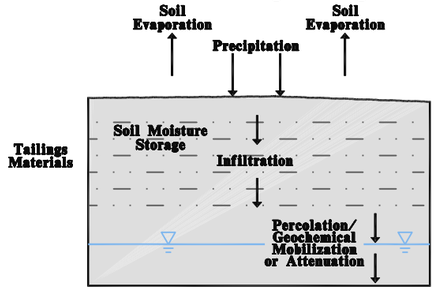
FIGURE: 3

JOB NUMBER:	DRAWN BY:	CHECKED BY:	APPROVED BY:	DATE:
	ARA	GSD	GSD	1/5/02

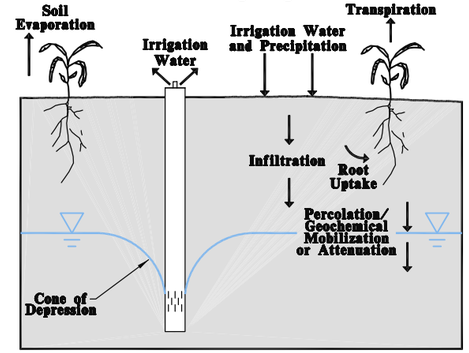
YERINGTON-XSC



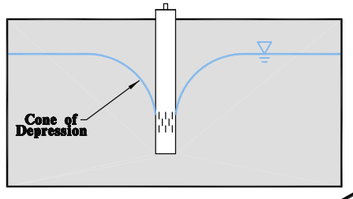
Cross Section Through Waste Rock Pile



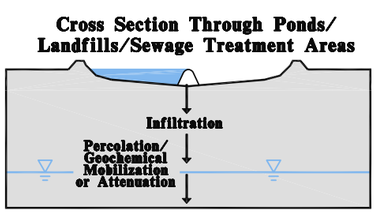
Cross Section Through Tailings Pile



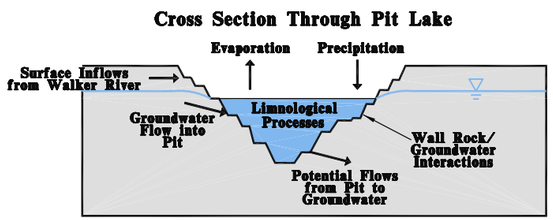
Cross Section Through Agricultural Area



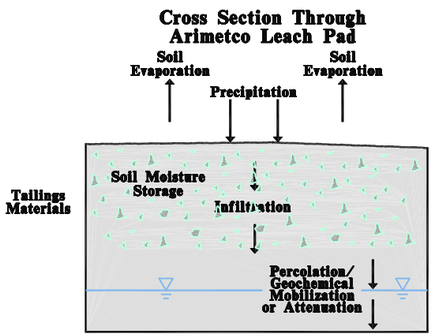
Cross Section of Pumpback and Domestic Well



Cross Section Through Ponds/ Landfills/Sewage Treatment Areas



Cross Section Through Pit Lake



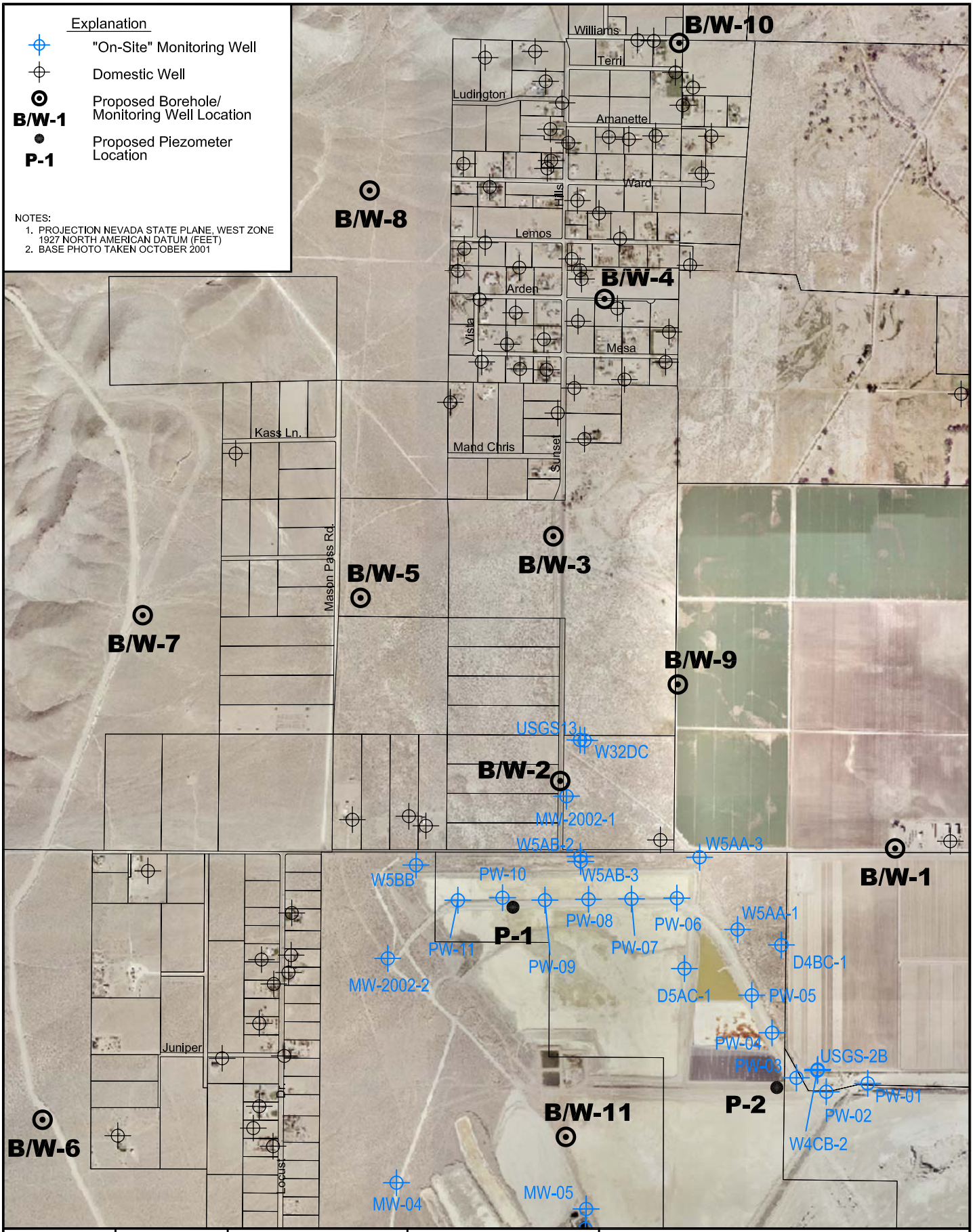
Cross Section Through Arimetco Leach Pad

BROWN AND CALDWELL Carson City, Nevada	DATE: January 2005 CLIENT: Atlantic Richfield Company PROJECT NUMBER: 21243

Figure 4

Site Conceptual Hydrogeologic Model

Carson City Cad: P:\ARCO\21243\Groundwater Conditions\CAD\January 2005\F21243004.dwg (1=1) 01/13/2005 08:04:49 RJJ



DATE:	PROJECT NUMBER:	SCALE:
Jan. 2005	21243	0 750 1500 SCALE IN FEET

BROWN AND CALDWELL
Carson City, Nevada

Atlantic Richfield Company

Figure 5

Proposed Borehole/Monitor Well and Piezometer Locations

Carson City Cad: P:\ARCO\21243\Groundwater Conditions\CAD\January 2005\F21243005.dwg (1=1) 01/13/2005 09:38:19 RJJ

Table 1. Domestic Well Information for the Sunset Hills Area

General Area - Station ID [1]	Location Address	NAD 27 W NV		Total Uranium Apr 04	Total Uranium Spt 04	Well Log Number	Total Depth	Screen Top	Screen Bottom	Screen Length	Diameter
		State Plane Y	State Plane X	(ug/L)	(ug/L)	NA	(ft)	(ft)	(ft)	(ft)	(in)
DW-65	264 Sunset Hills Dr	1,569,391.17	321,912.76	10.7	11.1		220.0				
DW-01	23 Mand Chris Dr	1,561,910.64	321,382.32				200.0				
DW-12	268 Sunset Hills Dr	1,569,397.70	322,603.97	8.25	9.8	55089	186.0	120	140	20	6.62
DW-44	34 E. Ward Ln	1,565,202.99	324,387.37		53.4	36010	180.0				
DW-31	191 Sunset Hills Dr	1,566,264.19	322,590.09	15	19.6	64859	220.0	135	180	45	8.62
DW-83	26 Williams Ln	1,566,805.65	323,966.72		11.8		160.0				
DW-36	125 Sunset Hills Dr	1,562,922.64	322,318.32	18.4	29.8		180.0				
DW-57	277 Sunset Hills Dr	1,570,136.30	321,548.76		**37.0**		147.0				
DW-21	17 Williams Ln	1,566,752.24	323,649.32		12.4		160.0				
DW-06	27 E. Lemos Ln	1,564,144.07	324,254.35	11.3	12.5	38309	150.0	130	150	20	6.62
DW-35	17 W. Lemos	1,564,425.41	321,892.96	11.3	13.5		201.0				
DW-13	24B E. Mesa Dr	1,563,373.25	324,011.08	**90.7**		67351	139.0	119	139	20	6.62
DW-52	120 Sunset Hills Dr	1,562,124.32	322,756.25	3.19	3.75	26693	139.0	119	139	20	6.62
DW-24	10 E. Mesa Dr	1,563,104.55	322,961.86				140.0				
DW-88	5 Vista Dr.	1,563,672.19	321,513.46		**33.1**		178.0	158	178	20	
DW-05	133 Sunset Hills Dr	1,563,288.81	322,569.35	**56.1**	**58.1**		150.0				
DW-40	12 E. Lemos Ln	1,564,410.07	323,164.85	11.5	14.2	59260	140.0	130	140	10	6.62
DW-62	9 W. Mesa Dr	1,563,131.95	322,022.32	29.9	**39.5**	29346	148.0	127	147	20	6.62
DW-08	148 Sunset Hills Dr	1,563,982.90	323,003.56	**40.2**		5608	150.0	110	150	40	10
DW-67	17 Amanette Way	1,565,597.32	323,548.27	8.39	8.29	39638	150.0	130	150	20	6
DW-26	3 E. Arden Dr	1,563,460.19	322,682.21	27.7	**50.8**	71630	140.0	120	140	20	6
DW-03	6 E. Lemos Ln	1,564,742.70	323,205.30	15	15.6		145.0				
DW-04	26 Mand Chris Dr	1,562,546.82	321,210.05	23.6	6.3	22350	145.0	124	144	20	6.62
DW-25	15 E. Mesa Dr	1,562,823.17	323,498.34	**47.6**		36183	121.0	100	120	20	6.62

Table 1. Domestic Well Information for the Sunset Hills Area - Continued

General Area - Station ID [1]	Location Address	NAD 27 W NV		Total Uranium Apr 04	Total Uranium Spt 04	Well Log Number	Total Depth	Screen Top	Screen Bottom	Screen Length	Diameter
		State Plane Y	State Plane X	(ug/L)	(ug/L)	NA	(ft)	(ft)	(ft)	(ft)	(in)
DW-22	25 Amanette Way	1,565,636.36	323,857.53	13.4	15.1	47206	140.0	100	140	40	6.62
DW-23	30 Amanette Way	1,565,989.32	324,170.64	46.6	40.8	16514	118.0				10.62
DW-16	10 W. Mesa Dr	1,563,231.64	322,144.33	44.9	56.9	26691	143.0	123	143	20	6.62
DW-66	11 Amanette Way	1,565,621.84	323,318.40	11.6	11.0	39955	140.0	116	136	20	6.62
DW-42	21 W. Lemos Ln	1,564,318.87	321,370.85	19.4	22.8	28567	160.0				6.62
DW-09	166 Sunset Hills Dr	1,564,889.73	322,955.81	16.6	17.0	23009	121.5	100.5	120.5	20	10.62
DW-07	148 Sunset Hills Dr	1,564,084.27	322,986.36	27.9	32.5	3794	110.0	60	110	50	6
DW-28	179 Sunset Hills Dr	1,565,713.87	322,645.09	20.8	23.9		120.0				
DW-30	173 Sunset Hills Dr	1,565,351.07	322,652.54	16.9	19.2	16375	117.0	100	117	17	6
DW-11	185 Sunset Hills Dr	1,566,017.06	322,778.38	12.4	12.1	20069	115.0	95	115	20	6.62
DW-34	26 W. Ward Ln	1,565,167.19	321,406.54		25.5		125.0				
DW-48	37 Amanette Way	1,565,617.06	324,218.96	108	109.0						
DW-33	9 E. Arden Dr	1,563,644.64	323,416.48		16.6						
DW-02	11 Arden Dr	1,563,579.32	321,962.12	45.7	50.3						
DW-68	12 Arden Dr	1,564,150.64	322,285.86	21	26.2						
DW-27	19 Arden Dr	1,563,777.45	321,793.91	32	43.1						
DW-46	22 Arden Dr	1,564,064.59	321,296.36	31.7	33.7						
DW-96	32 E. Lemos Ln	1,564,588.61	323,922.58		46.9						
DW-89	16 E. Lemos Ln	1,564,457.09	323,361.70		29.9		150.0				
DW-87	20 W. Lemos Ln										
DW-20	16 Luddington Ave	1,566,538.52	321,891.93	15.9	17.0						
DW-14	15 W. Mesa Dr	1,563,027.16	321,851.79	29	40.0						
DW-45	9 E. Mesa Dr	1,563,009.90	323,690.78	42.2							

Table 1. Domestic Well Information for the Sunset Hills Area - Continued

General Area - Station ID [1]	Location Address	NAD 27 W NV		Total Uranium Apr 04	Total Uranium Spt 04	Well Log Number	Total Depth	Screen Top	Screen Bottom	Screen Length	Diameter
		State Plane Y	State Plane X	(ug/L)	(ug/L)	NA	(ft)	(ft)	(ft)	(ft)	(in)
DW-85	16 E. Mesa Dr	1,563,103.95	323,582.18								
DW-99	18 Robin Rd	1,567,600.99	323,244.52		8.4		105.0	85	105	20	6
DW-32	113 Sunset Hills Dr	1,563,495.89	322,961.31		5.2		180.0				
DW-37	124 Sunset Hills Dr	1,562,726.25	322,919.95	8.4	8.95						
DW-86	139 Sunset Hills	1,563,542.74	322,529.44		74.5		120.0				
DW-90	145 Sunset Hills Dr.	1,563,885.99	322,284.18		59.3						
DW-10	154 Sunset Hills Dr	1,564,207.83	322,533.50	37.4	37.4						
DW-97	163 Sunset Hills Dr.	1,564,915.47	322,374.09		19.8		116.0				6
DW-29	171 Sunset Hills Dr	1,565,260.32	322,609.60	16.6	19.7		120.0				
DW-18	180 Sunset Hills Dr	1,565,540.56	322,570.15	20.4	21.0						
DW-50	197 Sunset Hills Dr	1,566,594.84	322,186.61	19.2	23.3						
DW-98	12 Terri Ln	1,566,528.46	322,970.22		13.3		140.0	120	140	20	
DW-19	24 Terri Lane	1,566,731.37	323,825.53	22.5	31.5						
DW-70	27 Terri Ln	1,566,193.19	324,288.75	44.6	47.7						
DW-41	19 W. Ward Ln	1,565,032.36	321,664.20	31	37.7						
DW-95	11 E. Ward Ln	1,565,012.53	323,178.05		10.2						
DW-93	18 E. Ward Ln	1,565,196.77	323,313.27		13.1						
DW-94	23 E. Ward Ln	1,564,976.57	323,558.86		27.0						

[1] Well locations surveyed using Garmin eTrex, handheld GPS unit March 8-9, 2004; May 4-5, 2004; Sept 13-15, 2004

[2] Ground surface elevations were estimated using aerial photography illustrating the well locations overlain with USGS topographic maps for the Site.

Table 2. Domestic Well Information for the Luzier and Locust Lane Areas

General Area - Station ID [1]	Location Address	NAD 27 W NV		Total Uranium Apr 04	Total Uranium Spt 04	Well Log Number	Total Depth	Screen Top	Screen Bottom	Screen Length	Diameter	Estimated Ground Surface Elevation [2]	Estimated Total Depth Elevation	Estimated Top of Screen Elevation
		State Plane Y	State Plane X	(ug/L)	(ug/L)	NA	(ft)	(ft)	(ft)	(ft)	(in)	(ft)	(ft)	(ft)
WDW019	21 Luzier Ln	1,557,484.37	326,973.67		**113.0**	78925	365	50	365	315	16	4,356	3,991	4,306
DW-73	15 Pine St	1,554,124.39	317,662.81	11.9	13.9	62472	390	200	260	60	6.62	4,522	4,132	4,322
DW-51	40 Luzier Ln	1,557,499.11	323,630.41		8.28		178					4,346	4,168	
DW-76	65 Locust Dr	1,554,462.92	319,293.24	21.5	23.2	67353	199	159	199	40	6.62	4,370	4,171	4,211
DW-78	68 Luzier Ln	1,557,370.44	320,388.42		23.2		160					4,368	4,208	
DW-77	69 Locust Dr	1,554,211.73	319,224.43	23.5	28.2		240					4,464	4,224	
DW-71	95 Kass Ln	1,562,080.35	319,115.04	24.3	**34.9**	91042	233	213	233	20	6.62	4,470	4,237	4,257
DW-72	91 Luzier Ln	1,557,046.57	317,532.41	**45.3**	**44.6**	42790	239	219	239	20	6.62	4,478	4,239	4,259
DW-39	30 Locust Dr	1,556,170.90	319,373.81	17.4	17.2	34158	155	135	155	20	6.62	4,410	4,255	4,275
DW-75	34 Locust Dr	1,556,006.59	319,630.76	17.8	20.1	35936	160	140	160	20	6.62	4,415	4,255	4,275
DW-63	47 Locust Dr	1,555,385.71	319,015.64	24.2	22.8	25113	147	127	147	20	8.62	4,430	4,283	4,303
DW-38	54 Locust Dr	1,555,008.70	319,294.98	**40.1**	**43.3**	27548	150	130	150	20	8.62	4,434	4,284	4,304
DW-64	35 Locust Dr	1,555,838.15	319,173.29	19.9	20.4		120					4,415	4,295	
DW-47	18 Locust Dr	1,556,657.87	319,380.85	18.1	18.7	9010	108	85	108	23	6.62	4,406	4,298	4,321
DW-49	75 Locust Dr	1,553,967.37	319,164.87	20.4	27.3		152					4,465	4,313	
DW-92	101 Kass Ln				NS		250							
DW-15	15 Juniper Way	1,555,016.95	318,865.54	22	22.3									
DW-91	14 Locust Dr	1,557,296.29	319,313.10		NS		160							
DW-74	27 Locust Dr	1,556,155.18	319,319.28	19.2	19.0									
WDW018	60 Luzier Ln	1,557,662.40	320,927.07	**30.5**	**30.2**							4,356		
DW-54	64 Luzier Ln	1,557,773.72	320,730.57	26.2	26.2									
WDW017	72 Luzier Ln	1,557,733.30	320,079.60	16.7	18.5									

[1] Well locations surveyed using Garmin eTrex, handheld GPS unit March 8-9, 2004; May 4-5, 2004; Sept 13-15, 2004

[2] Ground surface elevations were estimated using aerial photography illustrating the well locations overlain with USGS topographic maps for the Site.

Table 3. Proposed Stratigraphic Borehole, Monitor Well and Piezometer Locations

Well Identification	Rationale	Approach	Shallow	Intermediate	Deep
B/W-1	Assess shallow groundwater beneath irrigation area immediately north of the Mine Site.	Drill borehole to 200 feet bgs (@ 4,150 ft amsl); visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "shallow" aquifer; defer construction of separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones to Phase II; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	X	X
B/W-2	Assess ground water flow and solute transport pathways between existing monitor well locations.	Drill borehole to 150 feet bgs (i.e., @ 4,200 ft amsl); visually log stratigraphy; collect/archive soil core; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct a separate and adjacent monitor well with a 20-foot screen in "intermediate" zone; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	W5AB2	X	X
B/W-3	Assess ground water flow and solute transport pathways between existing monitor well and domestic well locations.	Drill borehole to 150 feet bgs (i.e., @ 4,200 ft amsl); visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	X	X
B/W-4	Assess ground water flow and solute transport pathways in the area of domestic wells with elevated uranium concentrations.	Drill borehole to 200 feet bgs (i.e., @4,200 ft amsl); visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	X	X
B/W-5	Assess zones in a "background" area potentially upgradient of domestic wells with elevated uranium concentrations.	Drill borehole to 150 feet bgs (i.e., @ 4,200 ft amsl); visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	X	X
B/W-6	Assess zones in a "background" area.	Drill borehole to 240 feet bgs (i.e., @ 4,236 ft amsl); visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	X	X
B/W-7	Assess zones in a "background" area potentially upgradient of domestic wells with elevated uranium concentrations.	Drill borehole to 200 feet bgs; visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	X	X

Table 3. Proposed Stratigraphic Borehole, Monitor Well and Piezometer Locations - Continued

Well Identification	Rationale	Approach	Shallow	Intermediate	Deep
B/W-8	Assess ground water flow and solute transport pathways between the MacArthur Mine and Sunset Hills areas.	Drill borehole to 200 feet bgs; visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	X	X
B/W-9	Assess ground water flow and solute transport pathways beneath the irrigation areas.	Drill borehole to 150 feet bgs (i.e., @ 4,200 ft amsl); visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5; survey wells.	X	X	X
B/W-10	Assess ground water flow and solute transport pathways in the area of domestic wells with elevated uranium concentrations.	Drill borehole to 200 feet bgs (i.e., @4,200 ft amsl); visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	X	X
B/W-11	Assess ground water flow and solute transport pathways down-gradient of MW-05.	Drill borehole to 200 feet bgs (i.e., @ 4,200 ft amsl); visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "deep" aquifer; construct separate and adjacent monitor wells with 20-foot screens in "intermediate" and "shallow" zones; develop wells and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	MW-05	X	Subsequent Phase (as needed)
B/W-12	Background south of the Mine Site	Drill borehole to 200 feet bgs or until bedrock is encountered; visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "shallow" aquifer; develop well and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	Subsequent Phase (as needed)	Subsequent Phase (as needed)
B/W-13	Background south of the Mine Site	Drill borehole to 200 feet bgs or until bedrock is encountered; visually log stratigraphy; collect/archive soil core; collect depth-discrete ground water samples for measurement/analysis of selected parameters (see Table 4); construct monitor well with 20-foot screen in "shallow" aquifer; develop well and collect ground water samples for measurement/analysis of selected parameters (see Table 5); survey wells.	X	Subsequent Phase (as needed)	Subsequent Phase (as needed)
P-1	Evaluate area of pumping influence around pumpback well PW-10 (relatively low pumping rate).	Drill borehole to equivalent depth of pumpback well; visually log stratigraphy; construct piezometer with screen interval that matches the pumpback well; install pressure transducer and data logger to collect continuous groundwater elevation data.	X	NA	NA

Table 3. Proposed Stratigraphic Borehole, Monitor Well and Piezometer Locations - Continued					
Well Identification	**Rationale**	**Approach**	**Shallow**	**Intermediate**	**Deep**
P-2	Evaluate area of pumping influence around pumpback well PW-3 (relatively high pumping rate).	Drill borehole to equivalent depth of pumpback well; visually log stratigraphy; construct piezometer with screen interval that matches the pumpback well; install pressure transducer and data logger to collect continuous groundwater elevation data.	X	NA	NA

Table 4. Proposed Field and Analytical Laboratory Parameter List				
Measurement / Parameter	**Field / Laboratory**	**Method**	**Measurement / Detection Limit**	**Units**
pH	Field Meter	EPA 150.1, Meter	0.1	Standard Units
Conductivity	Field Meter	EPA 120.1, Meter	1	uS/cm
Temperature	Field Meter	Standard Methods 212, Thermomemter	0.1	°Centigrade
Dissolved Oxygen	Field Meter	EPA 360.1, Probe	0.1	mg/L
ORP	Field Meter	SM 2580 B	1	mV
Iron (Total)	Hach Field Water Analysis Kit	Hach Method 8008 (FerroVer Method)	0.02 - 3.0	mg/L
Iron (Ferrous)	Hach Field Water Analysis Kit	Hach Method 8146 (1, 10 Phenanthroline Method)	0.02 - 3.0	mg/L
Sulfate	Hach Field Water Analysis Kit	Hach Method 8051 (SulfaVer 4 Method)	2	mg/L
Nitrate	Hach Field Water Analysis Kit	Hach Method 10020 (Chromotropic Acid Method)	0.2	mg/L
Alkalinity as $CaCO_3$	Hach Field Water Analysis Kit	Hach Method 8203 (Phenolphthalein Method)	10	mg/L
Uranium (total and dissolved)	Laboratory	EPA 200.8 ICP-MS	0.01	mg/L
Arsenic (total and dissolved)	Laboratory	EPA 200.8 ICP-MS	0.001	mg/L
Total Organic Carbon	Laboratory	EPA 415.1 (combustion/oxidation)	2.0	mg/L

Table 5. Proposed Analyte List

Parameter or Analyte	Standard [1]	Phase	Method	Method Detection Limit	Units
Alkalinity (Total as $CaCO_3$)	---	Total	SM 2320 B, Titrimetric	1.0	mg/L (as $CaCO_3$)
Aluminum	0.05 - 0.2	Total & Dissolved	EPA 200.7 ICP-OES	0.05	mg/L
Arsenic	0.05	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L
Barium	2	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L
Beryllium	0.004	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L
Bicarbonate (as $CaCO_3$)	---	Total	SM 2320 B	1.0	mg/L (as $CaCO_3$)
Boron	---	Total & Dissolved	EPA 200.7 ICP-OES	0.01	mg/L
Cadmium	0.005	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L
Calcium	---	Total & Dissolved	EPA 200.7 ICP-OES	0.1	mg/L
Chloride	250 - 400	Total	EPA 300.0 Ion Chromotography	0.5	mg/L
Cobalt	---	Total & Dissolved	EPA 200.8 ICP-MS	0.0005	mg/L
Copper	1.3	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L
Fluoride	4	Total	EPA 300.0 Ion Chromotography	0.1	mg/L
Gross Alpha/Beta	15/50	Total & Dissolved	EPA 900.0	1.0/2.0	pCi/L
Iron	0.3 - 0.6	Total & Dissolved	EPA 200.7 ICP-OES	0.05	mg/L
Magnesium	125 - 150	Total & Dissolved	EPA 200.7 ICP-OES	0.1	mg/L
Manganese	0.05 - 0.10	Total & Dissolved	EPA 200.8 ICP-MS	0.0005	mg/L
Nickel	0.1	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L
Nitrate (NO3 + NO2 as N)	10	Total	EPA 300.0 Ion Chromotography	0.05	mg/L as N
pH	---	Total	EPA 150.1 (SM 4500 H + B)	1 to 14	pH Units
Phosphorus	---	Total	EPA 365.3	0.05	mg/L
Potassium	---	Total & Dissolved	EPA 200.7 ICP-OES	0.5	mg/L
Radium 226	5	Total & Dissolved	EPA 903.0	0.2	pCi/L
Radium 228	---	Total & Dissolved	EPA 904.0	1.0	pCi/L
Sodium	---	Total & Dissolved	EPA 200.7 ICP-OES	0.1	mg/L
Strontium	---	Total & Dissolved	EPA 200.7 ICP-OES	0.5	mg/L
Sulfate	250 - 500	Total	EPA 300.0 Ion Chromotography	0.2	mg/L
Thorium 232	---	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L
Total Dissolved Solids	500 - 1000	Total & Dissolved	EPA 160.1 (SM 2450 C)	10	mg/L
Uranium	0.03	Total & Dissolved	EPA 200.8 ICP-MS	0.0003	mg/L
Vanadium	---	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L
Zinc	5	Total & Dissolved	EPA 200.8 ICP-MS	0.001	mg/L

Notes:

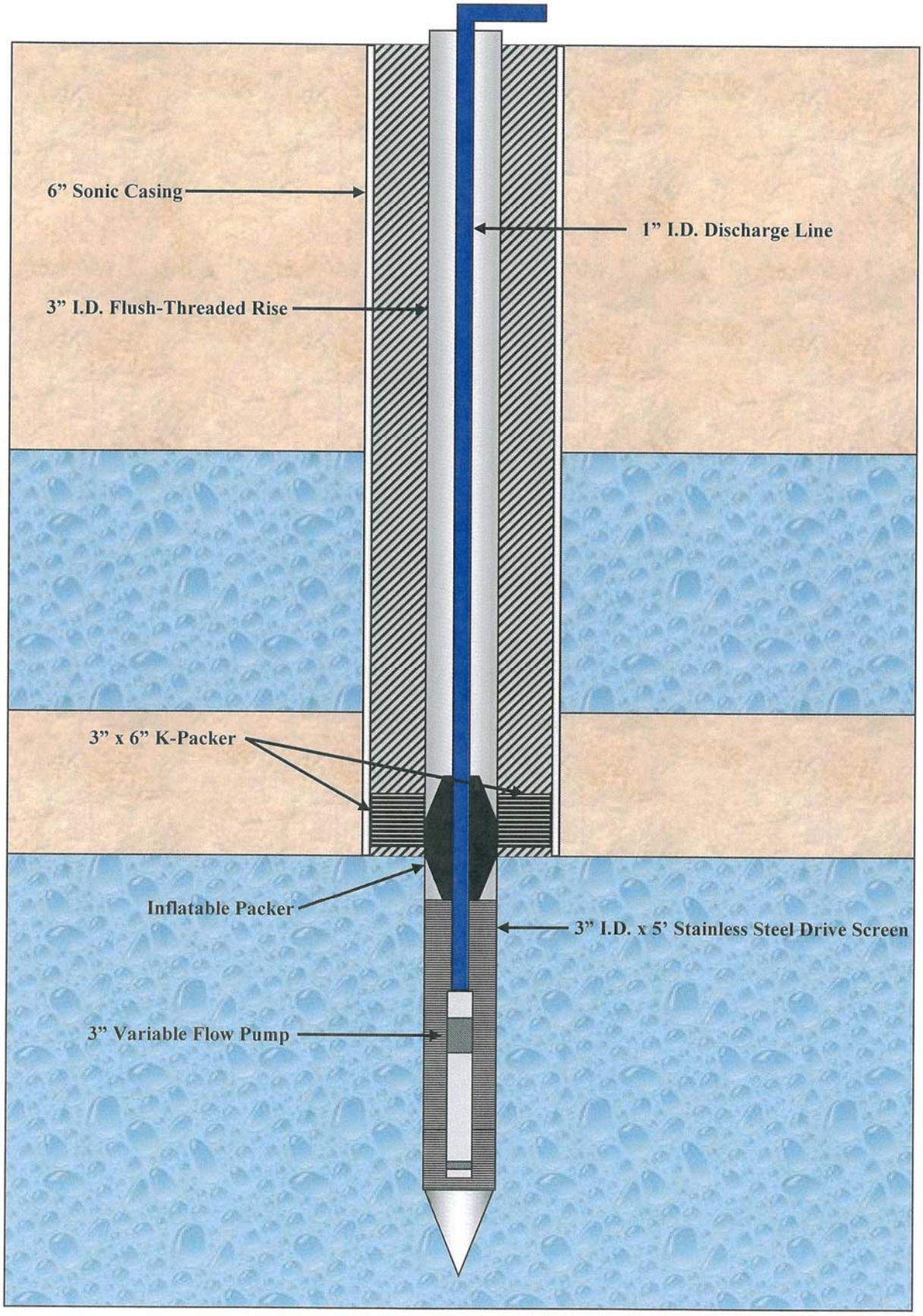
(1) Standard is for reference purposes only.

ICP-MS Inductively Coupled Plasma-Mass Spectrometry

ICP-OES Inductively Coupled Plasma - Optical Emission Spectrometry

APPENDIX A

DEPTH-SPECIFIC GROUNDWATER SAMPLING ILLUSTRATION


6" Sonic Casing
1" I.D. Discharge Line
3" I.D. Flush-Threaded Rise
3" x 6" K-Packer
Inflatable Packer
3" I.D. x 5' Stainless Steel Drive Screen
3" Variable Flow Pump

APPENDIX B

FIELD EQUIPMENT INFORMATION

Iron, Total

✔Method 8008

FerroVer® Method*

Powder Pillows or AccuVac® Ampuls

(0.02 to 3.00 mg/L)

Scope and Application: For water, wastewater, and seawater; digestion is required for determining total iron; USEPA approved for reporting wastewater analysis**

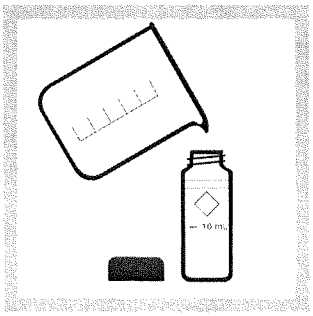
* Adapted from *Standard Methods for the Examination of Water and Wastewater*

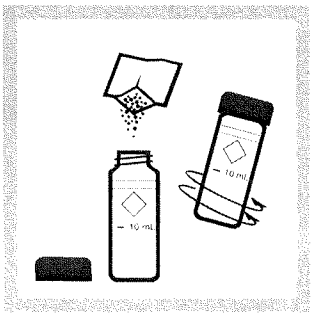
** *Federal Register*, June 27, 1980; 45 (126:43459)

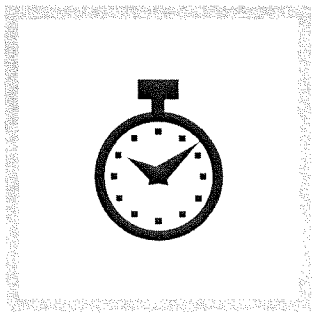
Tips and Techniques

- Digestion is required for determining total iron for EPA reporting purposes. See *Section 4* on page *63* for the digestion procedure.
- For more accurate results, determine a reagent blank value for each new lot of reagent. Follow the procedure using deionized water in place of the sample. Subtract the reagent blank value from the final results or perform a reagent blank adjust. See the instrument manual for more information on *Running a Reagent Blank*.
- After adding reagent, an orange color will form if iron is present.
- Accuracy is not affected by undissolved powder.

Powder Pillows





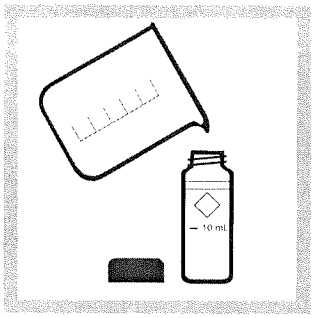


1. Touch **Hach Programs**.
   Select program **265 Iron, FerroVer**.
   Touch **Start**.

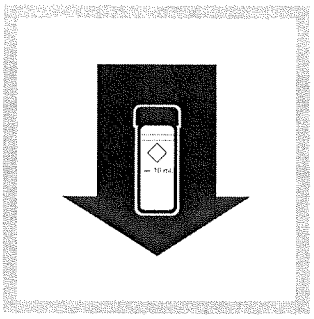
2. Fill a clean, round sample cell with 10 mL of sample.

3. Add the contents of one FerroVer Iron Reagent Powder Pillow to the sample cell (the prepared sample). Swirl to mix.

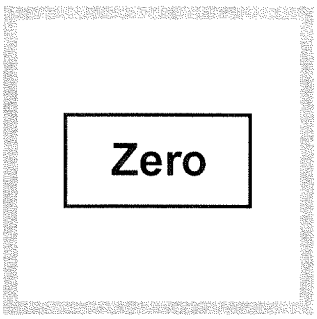
4. Touch the timer icon.
   Touch **OK**.
   A three-minute reaction period will begin.
   (Allow samples that contain rust to react for at least 5 minutes.)



5. Fill another sample cell (the blank) with 10 mL of sample.



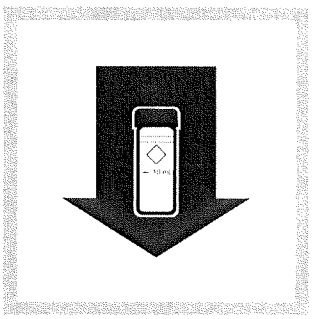
6. When the timer beeps, place the blank into the cell holder.



7. Touch **Zero**.

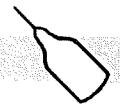
The display will show:

0.00 mg/L Fe



8. Place the prepared sample into the cell holder.

Results will appear in mg/L Fe.



AccuVac Ampul Method 267 nm

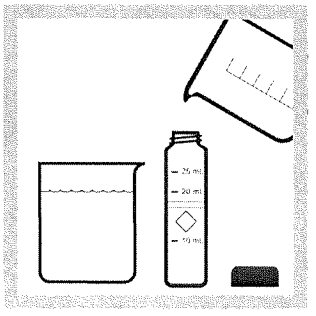
1. Touch

Hach Programs.

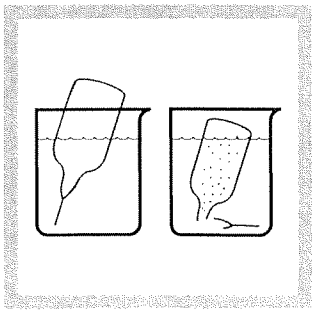
Select program

267 Iron, FerroVer AV.

Touch **Start**.

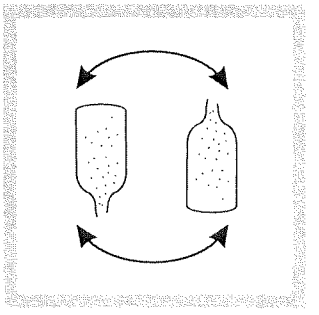


2. Fill a sample cell with 25 mL of sample. Collect at least 40 mL of sample in a 50-mL beaker.

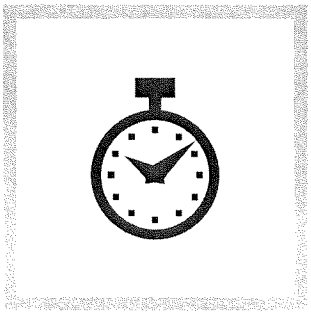


3. Fill a FerroVer Iron AccuVac® Ampul with sample.

Keep the tip immersed while the ampule fills completely.



4. Quickly invert the ampule several times to mix. Wipe off any liquid or fingerprints.

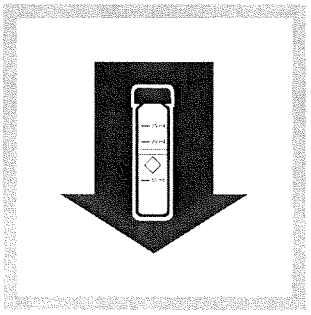


5. Touch the timer icon.

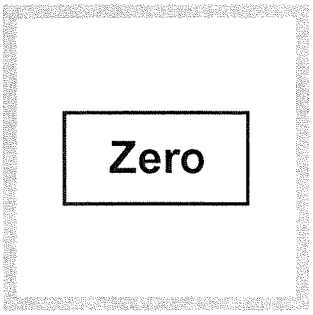
Touch **OK**.

A three-minute reaction period will begin.

(Samples that contain rust should react for at least 5 minutes.)



6. When the timer beeps, place the blank into the cell holder.



7. Touch **Zero**.

The display will show:

0.00 mg/L Fe

8. Place the AccuVac Ampul into the cell holder.

Results will appear in mg/L Fe.

Interferences

Interfering Substance	Interference Levels and Treatments
Calcium, Ca^{2+}	No effect at less than 10,000 mg/L as $CaCO_3$.
Chloride, Cl^-	No effect at less than 185,000 mg/L.
Copper, Cu^{2+}	No effect. Masking agent is contained in FerroVer Reagent.
High Iron Levels	Inhibit color development. Dilute sample and re-test to verify results.
Iron Oxide	Requires mild, vigorous or Digesdahl digestion. After digestion, adjust sample to pH 3–5 with sodium hydroxide (Cat. No. 2450-32), then analyze.
Magnesium	No effect at 100,000 mg/L as calcium carbonate.
Molybdate Molybdenum	No effect at 50 mg/L as Mo.
High Sulfide Levels, S^{2-}	**1.** Treat in fume hood or well-ventilated area. Add 5 mL hydrochloric acid, ACS (Cat. No. 134-49) to 100 mL sample in a 250-mL Erlenmeyer flask. Boil 20 minutes. **2.** Cool. Adjust pH to 3–5 with Sodium Hydroxide (Cat. No. 2450-32). Readjust volume to 100 mL with deionized water. **3.** Analyze.
Turbidity	**1.** Add 0.1 g scoop of RoVer® Rust Remover (Cat. No. 300-01) to the blank. Swirl to mix. **2.** Zero the instrument with this blank. **3.** If sample remains turbid, add three 0.2 g scoops of RoVer to a 75-mL sample. Let stand 5 minutes. **4.** Filter through a Glass Membrane Filter (Cat. No. 2530-00) and Filter Holder (Cat No. 2340-00). **5.** Use filtered sample in steps 2 and 5.
Extreme Sample pH	Adjust pH to 3–5. See *Section 3.3 Interferences* on page *50*.
Highly Buffered Samples	Adjust pH to 3–5. See *Section 3.3 Interferences* on page *50*.

Sample Collection, Storage and Preservation

Collect samples in acid-cleaned glass or plastic containers. No acid addition is necessary if analyzing the sample immediately. To preserve samples, adjust the pH to 2 or less with concentrated nitric acid (about 2 mL per liter) (Cat. No. 152-49). Preserved samples may be stored up to six months at room temperature. Before analysis, adjust the pH to between 3 and 5 with 5.0 N Sodium Hydroxide Standard Solution (Cat. No. 2450-32). Correct the test result for volume additions; see *Section 3.1.3 Correcting for Volume Additions* on page *43*.

If only dissolved iron is to be determined, filter the sample before acid addition.

Accuracy Check

Standard Additions Method (Sample Spike)

1. After reading test results, leave the sample cell (unspiked sample) in the instrument.
2. Touch **Options**. Touch **Standard Additions**. A summary of the standard additions procedure will appear.
3. Touch **OK** to accept the default values for standard concentration, sample volume, and spike volumes. Touch **Edit** to change these values. After values are accepted, the unspiked sample reading will appear in the top row. See *Standard Additions* in the instrument manual for more information.
4. Snap the neck off an Iron Voluette Ampule Standard, 50-mg/L.
5. Prepare a 0.1 mL sample spike by adding 0.1 mL of standard to the unspiked sample. Touch the timer icon. After the timer beeps, read the result.
6. Prepare a 0.2 mL sample spike by adding 0.1 mL of standard to the 0.1 mL sample spike. Touch the timer icon. After the timer beeps, read the result.
7. Prepare a 0.3 mL sample spike by adding 0.1 mL of standard to the 0.2 mL sample spike. Touch the timer icon. After the timer beeps, read the result. Each addition should reflect approximately 100% recovery.

Note: *For AccuVac Ampuls, fill three mixing cylinders (Cat. No. 1896-41) with 50-mL of sample and spike with 0.2 mL, 0.4 mL, and 0.6 mL of standard. Transfer 40 mL from each of the three mixing cylinders to three 50-mL beakers (Cat. No. 500-41H). Analyze each standard addition sample as described in the procedure above. Accept each standard additions reading by touching* **Read**. *Each addition should reflect approximately 100% recovery.*

8. After completing the sequence, touch **Graph** to view the best-fit line through the standard additions data points, accounting for matrix interferences. Touch **View: Fit**, then select **Ideal Line** and touch **OK** to view the relationship between the sample spikes and the "Ideal Line" of 100% recovery.

See *Section 3.2.2 Standard Additions* on page *46* for more information.

Standard Solution Method

1. Prepare a 1.00-mg/L Fe standard solution by pipetting 1.00 mL of Iron Standard Solution, 100-mg/L, into a 100-mL volumetric flask. Dilute to the mark with deionized water. Stopper and invert to mix. Prepare this solution daily. Perform the iron procedure as described above.
2. To adjust the calibration curve using the reading obtained with the 1.00 mg/L Standard Solution, touch **Options** on the current program menu. Touch **Standard Adjust**.

3. Touch **On**. Touch **Adjust** to accept the displayed concentration. If an alternate concentration is used, touch the number in the box to enter the actual concentration, then touch **OK**. Touch **Adjust**.

See *Section 3.2.4 Adjusting the Standard Curve* on page *49* for more information.

Method Performance

Precision

Standard: 1.000 mg/L Fe

Program	95% Confidence Limits of Distribution
265	0.989–1.011 mg/L Fe
267	0.977–1.023 mg/L Fe

See *Section 3.4.3 Precision* on page *53* for more information, or if the standard concentration did not fall within the specified range.

Sensitivity

Program	Portion of Curve	ΔAbs	Δ Concentration
265	Entire range	0.010	0.022 mg/L Fe
267	Entire range	0.010	0.023 mg/L Fe

See *Section 3.4.5 Sensitivity* on page *54* for more information.

Summary of Method

FerroVer Iron Reagent converts all soluble iron and most insoluble forms of iron in the sample to soluble ferrous iron. The ferrous iron reacts with the 1,10 phenanthroline indicator in the reagent to form an orange color in proportion to the iron concentration. Test results are measured at 510 nm.

Required Reagents

Description	Quantity Required per test	Unit	Cat. No.
FerroVer® Iron Reagent Powder Pillows (for 10-mL sample)	1 pillow	100/pkg	21057-69
or			
FerroVer® Iron Reagent AccuVac® Ampuls	1 ampul	25/pkg	25070-25

Required Apparatus

Sample Cells, 10-mL, w/cap	2	6/pkg	24276-06
Beaker, 50-mL	1	each	500-41H

Required Standards

Iron Standard Solution, 100-mg/L		100 mL	14175-42
Iron Standard Solution, 10-mL Voluette® Ampule, 50-mg/L as Fe		16/pkg	14254-10
Water, deionized		4 liters	272-56

Iron, Ferrous

Method 8146

1, 10 Phenanthroline Method*

Powder Pillows or AccuVac® Ampuls

(0.02 to 3.00 mg/L)

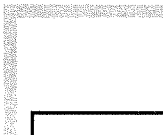
Scope and Application: For water, wastewater, and seawater

* Adapted from *Standard Methods for the Examination of Water and Wastewater*, 15th ed. 201 (1980)

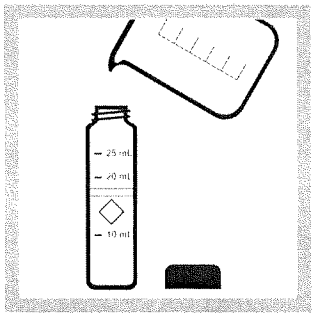
Tips and Techniques

- Analyze samples as soon as possible to prevent air oxidation of ferrous iron to ferric iron, which is not determined.
- For more accurate results, determine a reagent blank value for each new lot of reagent. Follow the procedure using deionized water in place of the sample. Subtract the reagent blank value from the final results or perform a reagent blank adjust. See the instrument manual for more information on *Running a Reagent Blank*.
- If ferrous iron is present, an orange color will form after adding the reagent.

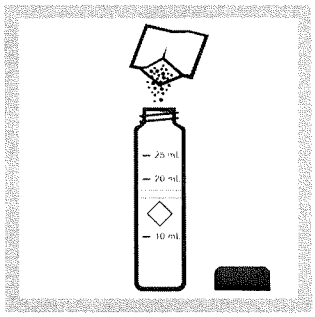
Powder Pillows



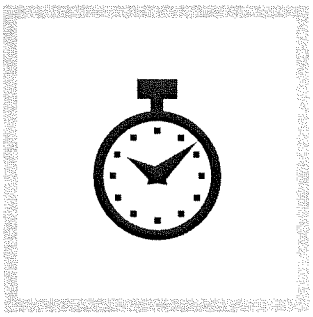
1. Touch **Hach Programs**.
Select program **255 Iron, Ferrous**.
Touch **Start**.



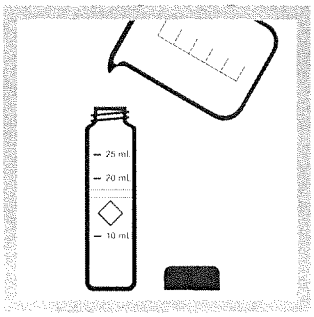
2. Fill a clean, round sample cell with 25 mL of sample.



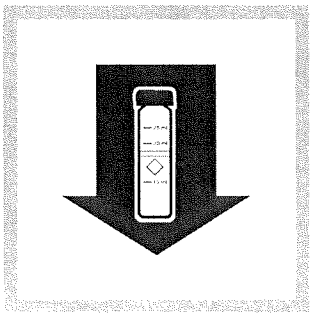
3. Add the contents of one Ferrous Iron Reagent Powder Pillow to the sample cell (the prepared sample). Swirl to mix.



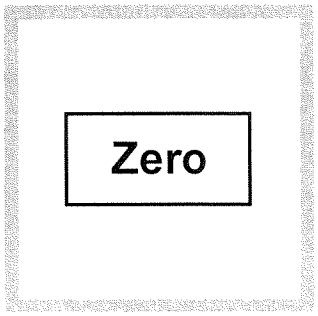
4. Touch the timer icon.
Touch **OK**.
A three-minute reaction period will begin.



5. Fill a second round sample cell with 25 mL of sample (the blank).



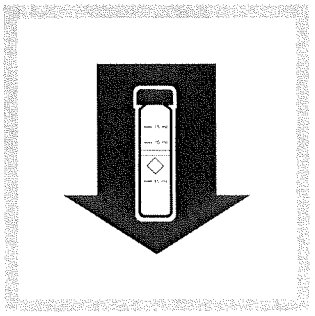
6. When the timer beeps, place the blank into the cell holder.



7. Touch **Zero**.

The display will show:

0.00 mg/L Fe^{2+}



8. Place the prepared sample into the cell holder.

Results will appear in mg/L Fe^{2+}.

AccuVac Ampul Method 8146

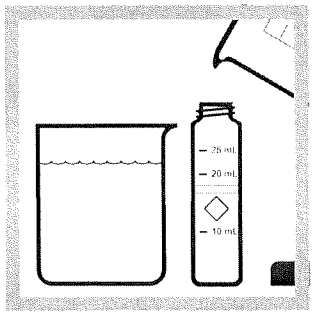
1. Touch

Hach Programs.

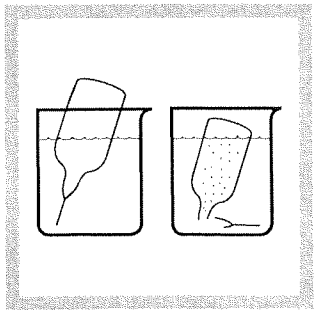
Select program

257 Iron, Ferrous AV.

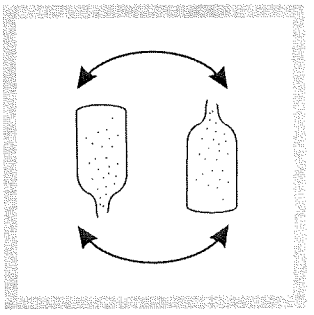
Touch **Start**.



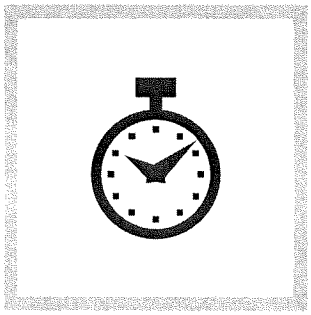
2. Fill a sample cell with 25 mL of sample (the blank). Collect at least 40 mL of sample in a 50-mL beaker.



3. Fill a Ferrous Iron AccuVac® Ampul with sample. Keep the tip immersed while the ampule fills completely.



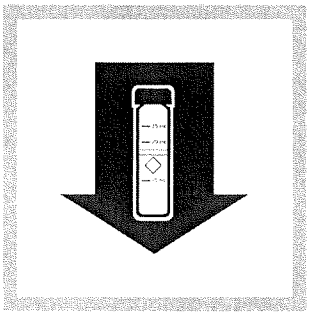
4. Quickly invert the ampule several times to mix. Wipe off any liquid or fingerprints.



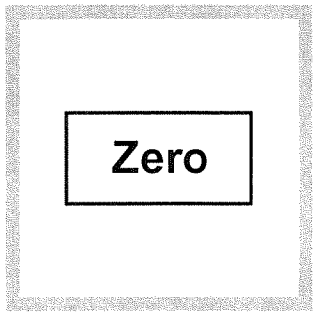
5. Touch the timer icon.

Touch **OK**.

A three-minute reaction period will begin.



6. When the timer beeps, place the blank into the cell holder.



7. Touch **Zero**.

The display will show:

0.00 mg/L Fe^{2+}

8. Place the AccuVac Ampul into the cell holder.

Results will appear in mg/L Fe^{2+}.

Sample Collection, Storage and Preservation

Collect samples in plastic or glass bottles. Analyze samples as soon as possible after collection.

Accuracy Check

Standard Solution Method

1. Prepare a ferrous iron stock solution (100-mg/L Fe^{2+}) by dissolving 0.7022 grams of Ferrous Ammonium Sulfate, hexahydrate, in deionized water. Dilute to one liter in a Class A volumetric flask. In a 100-mL Class A volumetric flask, dilute 1.00 mL of this solution to 100 mL with deionized water to make a 1.0-mg/L standard solution. Prepare this solution immediately before use. Perform the iron procedure as described above.
2. To adjust the calibration curve using the reading obtained with the 1.0-mg/L Fe^{2+} Standard Solution, touch **Options** on the current program menu. Touch **Standard Adjust.**
3. Touch **On**. Touch **Adjust** to accept the displayed concentration. If an alternate concentration is used, touch the number in the box to enter the actual concentration, then touch **OK**. Touch **Adjust**.

See *Section 3.2.4 Adjusting the Standard Curve* on page *49* for more information.

Method Performance

Precision

Standard: 1.000 mg/L Fe

Program	95% Confidence Limits of Distribution
255	0.989–1.011 mg/L Fe
257	0.977–1.023 mg/L Fe

See *Section 3.4.3 Precision* on page *53* for more information, or if the standard concentration did not fall within the specified range.

Sensitivity

Program	Portion of Curve	ΔAbs	ΔConcentration
255	Entire range	0.010	mg/L Fe
257	Entire range	0.010	0.023 mg/L Fe

See *Section 3.4.5 Sensitivity* on page *54* for more information.

Summary of Method

The 1,10 phenanthroline indicator in the Ferrous Iron Reagent reacts with ferrous iron in the sample to form an orange color in proportion to the iron concentration. Ferric iron does not react. The ferric iron (Fe^{3+}) concentration can be determined by subtracting the ferrous iron concentration from the results of a total iron test. Test results are measured at 510 nm.

Required Reagents

Description	Quantity Required per test	Unit	Cat. No.
Ferrous Iron Reagent AccuVac® Ampuls	1 ampul	25/pkg	25140-25
or			
Ferrous Iron Reagent Powder Pillows	1 pillow	100/pkg	1037-69

Required Apparatus

Beaker, 50-mL	1	each	500-41H
Sample Cells, 10-20-25 mL, w/cap	2	6/pkg	24019-06

Required Standards

Ferrous Ammonium Sulfate, hexahydrate, ACS	113 g		11256-14
Water, deionized	4 liters		272-56

FOR TECHNICAL ASSISTANCE, PRICE INFORMATION AND ORDERING:
In the U.S.A. – **Call toll-free 800-227-4224**
Outside the U.S.A. – **Contact the HACH office or distributor serving you.**
On the Worldwide Web – **www.hach.com**; E-mail – **techhelp@hach.com**

HACH COMPANY
WORLD HEADQUARTERS
Telephone: (970) 669-3050
FAX: (970) 669-2932

Sulfate

✔Method 8051

SulfaVer 4 Method*

Powder Pillows or AccuVac® Ampuls

(2 to 70 mg/L)

Scope and Application: For water, wastewater, and seawater; USEPA accepted for reporting wastewater analyses

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* Adapted from *Standard Methods for the Examination of Water and Wastewater.* Procedure is equivalent to USEPA method 375.4 for wastewater.

Tips and Techniques

- You must adjust the standard curve for each new lot of reagent. See *Standard Solutions* following these steps.
- For best results, perform a new calibration for each lot of reagent. See *Calibration Standard Preparation* following these steps.
- For more accurate results, determine a reagent blank value for each new lot of reagent. Follow the procedure using deionized water in place of the sample. Subtract the reagent blank value from the final results or perform a reagent blank adjust. See the instrument manual for more information on *Running a Reagent Blank*.
- Filter highly colored or turbid samples using filter paper (Cat. No. 1894-57) and a funnel (Cat. No. 1083-67). Use this sample in *step 5*.
- After adding reagent to the sample, a white turbidity will form if sulfate is present.
- Undissolved powder that has settled does not affect accuracy.
- SulfaVer® 4 contains barium chloride. The final solution will contain barium chloride (D005) at a concentration regulated as a hazardous waste by the Federal RCRA. See *Section 5* for more information on proper disposal of these materials.

Powder Pillows

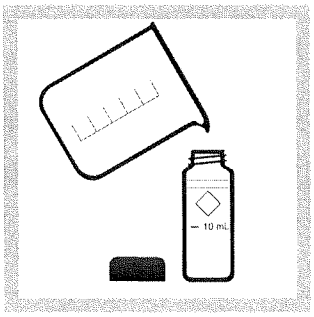
1. Touch

Hach Programs.

Select program

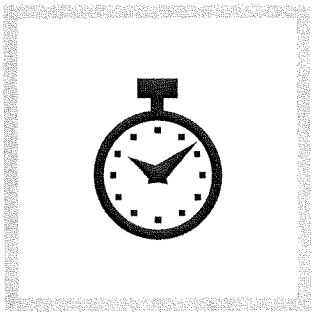
680 Sulfate.

Touch **Start**.



2. Fill a clean sample cell with 10 mL of sample.

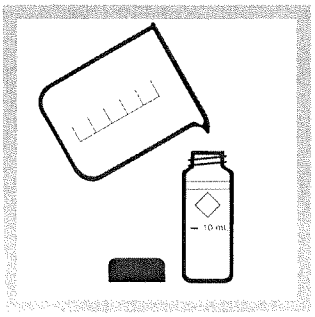
3. Add the contents of one SulfaVer 4 Reagent Powder Pillow to the sample cell (the prepared sample). Swirl to mix.



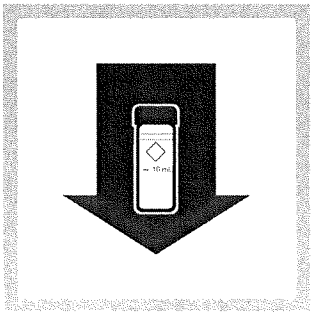
4. Touch the timer icon.

Touch **OK**.

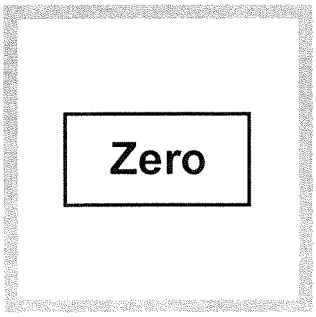
A five-minute reaction period will begin. Do not disturb the cell during this time.



5. Fill a second sample cell with 10 mL of sample (the blank).



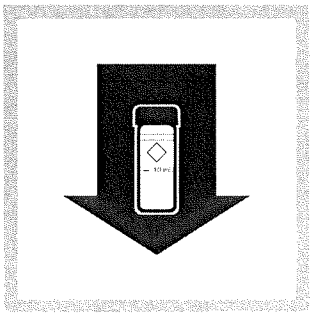
6. When the timer beeps, place the blank into the cell holder.



7. Touch **Zero**.

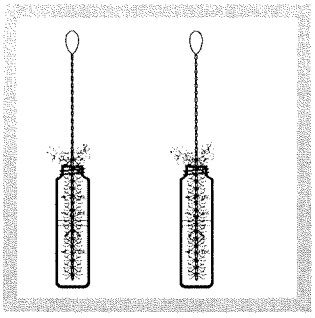
The display will show:

0 mg/L SO_4^{2-}



8. Within five minutes after the timer beeps, place the prepared sample into the cell holder.

Results will appear in mg/L SO_4^{2-}.



9. Clean the sample cells with soap and a brush.

AccuVac Ampul

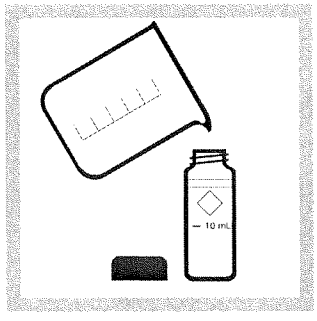
1. Touch

Hach Programs.

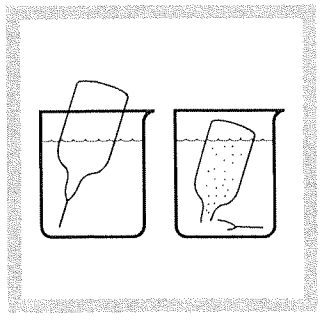
Select program

685 Sulfate AV.

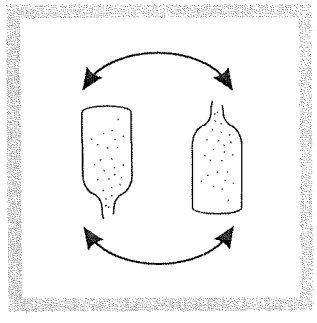
Touch **Start**.



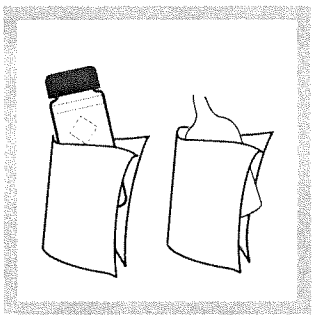
2. Fill a clean sample cell with 10 mL of sample (the blank). Collect at least 40 mL of sample in a 50-mL beaker.



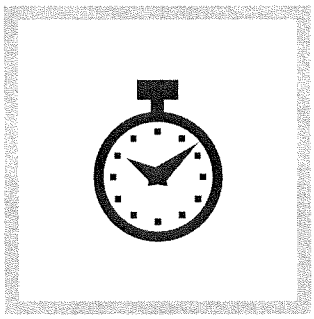
3. Fill a SulfaVer 4 Sulfate AccuVac Ampul with sample. Keep the tip immersed until the ampule fills completely.



4. Quickly invert the ampule several times to mix.



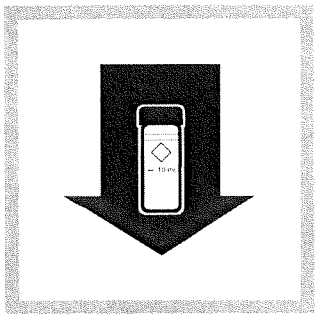
5. Wipe off any liquid or fingerprints from the blank and the ampule.



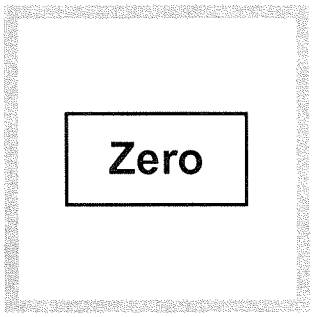
6. Touch the timer icon.

Touch **OK**.

A five-minute reaction period will begin. Do not disturb the cell during this time.



7. When the timer beeps, place the blank into the cell holder.



8. Touch **Zero**.

The display will show:

0 mg/L SO_4^{2-}

9. Within five minutes after the timer beeps, place the ampule into the cell holder.

Results will appear in mg/L SO_4^{2-}.

Interferences

Interfering Substance	Interference Levels and Treatment
Calcium	Greater than 20,000 mg/L as $CaCO_3$
Chloride	Greater than 40,000 mg/L as Cl
Magnesium	Greater than 10,000 mg/L as $CaCO_3$
Silica	Greater than 500 mg/L as SiO_2

Sample Collection, Storage, and Preservation

Collect samples in clean plastic or glass bottles. Samples may be stored up to 7 days by cooling to 4 °C (39 °F) or lower. Warm to room temperature before analysis.

Accuracy Check

Standard Additions Method (Sample Spike)

1. After reading test results, leave the sample cell (unspiked sample) in the instrument.
2. Touch **Options**. Touch **Standard Additions**. A summary of the standard additions procedure will appear.
3. Touch **OK** to accept the default values for standard concentration, sample volume, and spike volumes. Touch **Edit** to change these values. After values are accepted, the unspiked sample reading will appear in the top row. See *Standard Additions* in the instrument manual for more information.
4. Snap the neck off a Sulfate 2-mL Ampule Standard, 1000-mg/L sulfate.
5. Prepare three sample spikes. Fill three mixing cylinders (Cat. No. 1896-40) with 25 mL of sample. Use the TenSette Pipet to add 0.1 mL, 0.2 mL, and 0.3 mL of standard, respectively, to each sample and mix thoroughly.
6. Transfer 10 mL of each sample spike to a clean sample cell and analyze each sample spike as described in the procedure above, starting with the 0.1 mL sample spike. Accept each standard additions reading by touching **Read**. Each addition should reflect approximately 100% recovery.

Note: *For AccuVac Ampuls, fill three Mixing Cylinders (Cat. No. 1896-41) with 50 mL of sample and spike with 0.2 mL, 0.4 mL, and 0.6 mL of standard. Transfer 40 mL from each of the three mixing cylinders to three 50-mL Beakers (Cat. No. 500-41). Analyze each standard addition sample as described in the procedure above. Accept each standard additions reading by touching* **Read**. *Each addition should reflect approximately 100% recovery.*

7. After completing the sequence, touch **Graph** to view the best-fit line through the standard additions data points, accounting for matrix interferences. Touch **View: Fit**, then select **Ideal Line** and touch **OK** to view the relationship between the sample spikes and the "Ideal Line" of 100% recovery.

See *Section 3.2.2 Standard Additions* on page *46* for more information.

Standard Solutions

Prepare a 70-mg/L sulfate standard solution as follows:

1. Using Class A glassware, Pipet 7 mL of Sulfate Standard Solution, 1000-mg/L, into a 100-mL volumetric flask. Dilute to the mark with deionized water. Prepare this solution daily. Perform the SulfaVer procedure as described above.
2. To adjust the calibration curve using the reading obtained with the 70-mg/L standard solution, touch **Options** on the current program menu. Touch **Standard Adjust**.
3. Touch **On**. Touch **OK** to accept the displayed concentration. If an alternate concentration is used, touch **Adjust** and then enter the actual concentration. Touch **OK**.

See *Section 3.2.4 Adjusting the Standard Curve* on page *49* for more information.

Calibration Standard Preparation

To perform a sulfate calibration using the SulfaVer method, use Class A glassware to prepare calibration standards containing 10, 20, 30, 40, 50, 60 and 70 mg/L SO_4^{2-} as follows:

1. Into seven different 100-mL Class A volumetric flasks, pipet 1, 2, 3, 4, 5, 6, and 7 mL of the 1000-mg/L Sulfate Standard Solution.
2. Dilute to the mark with deionized water. Mix thoroughly.
3. Using the SulfaVer method and the calibration procedure described in the User-Entered Programs section of the spectrophotometer *Instrument Manual*, generate a calibration curve from the calibration standards prepared above.

Method Performance

Precision

Standard: 30 mg/L SO_4^{2-}

Program	95% Confidence Limits of Distribution
680	27–33 mg/L SO_4^{2-}
685	18–43 mg/L SO_4^{2-}

See *Section 3.4.3 Precision* on page *53* for more information, or if the standard concentration did not fall within the specified range.

Sensitivity

Program	ΔAbs	ΔConcentration
680	0.010	1 mg/L SO_4^{2-}
685	0.010	2 mg/L SO_4^{2-}

See *Section 3.4.5 Sensitivity* on page *54* for more information.

Summary of Method

Sulfate ions in the sample react with barium in the SulfaVer 4 and form a precipitate of barium sulfate. The amount of turbidity formed is proportional to the sulfate concentration. The SulfaVer 4 also contains a stabilizing agent to hold the precipitate in suspension. Test results are measured at 450 nm.

Required Reagents

Description	Quantity Required per test	Unit	Cat. No.
SulfaVer® 4 Reagent Powder Pillows	1	100/pkg	21067-69
or			
SulfaVer® 4 Sulfate Reagent AccuVac Ampuls	1	25/pkg	25090-25

Required Apparatus

Beaker, 50-mL	1	each	500-41
Sample cells, 10-mL, w/cap	2	6/pkg	24276-06

Required Standards

Sulfate Standard Solution, 1000-mg/L		500 mL	21757-49
Sulfate Standard Solution, 1000-mg/L, 2-mL Ampules		20/pkg	21757-20
Water, deionized		4 liters	272-56

Nitrate

Method 10020

Chromotropic Acid Method

Test 'N Tube™ Vials

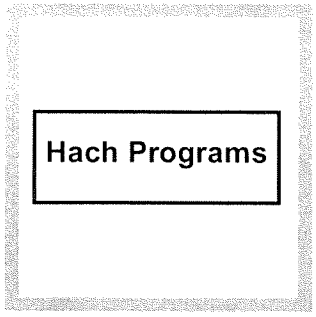
HR (0.2 to 30.0 mg/L NO_3^-–N)

Scope and Application: For water and wastewater

Tips and Techniques

- For more accurate results, determine a reagent blank value for each new lot of reagent. Follow the procedure using deionized water (nitrate-free) in place of the sample. Subtract the reagent blank value from the final results or perform a reagent blank adjust. See the instrument manual for more information on *Running a Reagent Blank*.
- This test is technique-sensitive. Invert the vials as described here to avoid low results: Hold the vial in a vertical position with the cap pointing up. Turn the vial upside-down. Wait for all of the solution to flow down to the cap. Pause. Return the vial to an upright position. Wait for all the solution to flow to the bottom of the vial. This process equals one inversion.
- Wipe the outside of sample cells before each insertion into the instrument cell holder. Use a damp towel followed by a dry one to remove fingerprints or other marks.

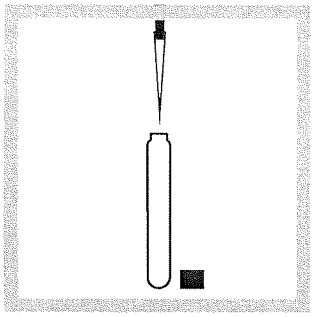
Test 'N Tube — Method 10020



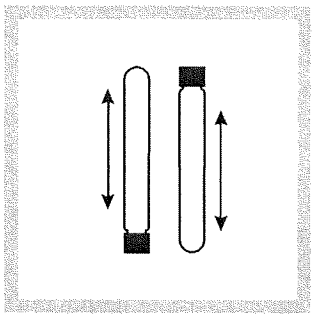
1. Touch **Hach Programs**.

Select program **344 N, Nitrate HR TNT**.

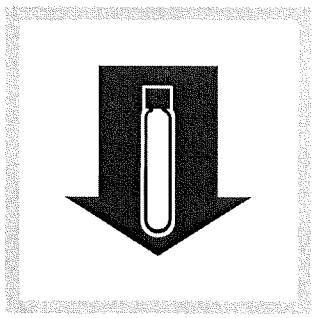
Touch **Start**.



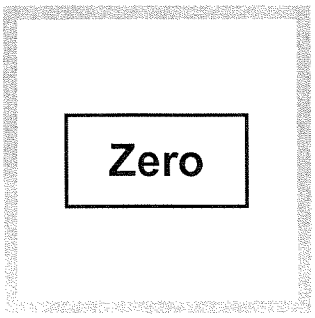
2. Remove the cap from a NitraVer X Reagent A Test 'N Tube vial and add 1.00 mL of sample (this is the blank).



3. Cap the tube and invert ten times to mix.



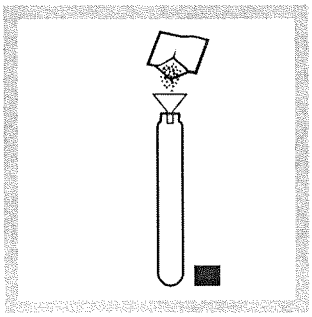
4. Wipe the blank and place it into the cell holder.



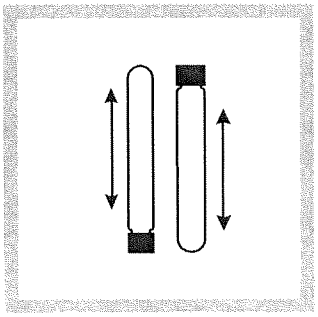
5. Touch **Zero**.

The display will show:

0.0 mg/L NO_3^-–N

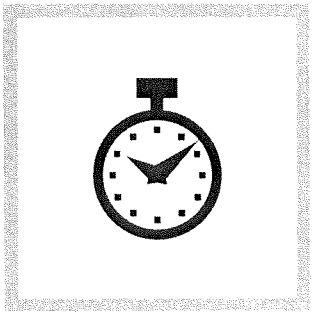


6. Remove the vial from the instrument. Using a funnel, add the contents of one NitraVer X Reagent B Powder Pillow to the vial.



7. Cap and invert ten times to mix (this is the *prepared sample*).

Some solid matter will not dissolve.

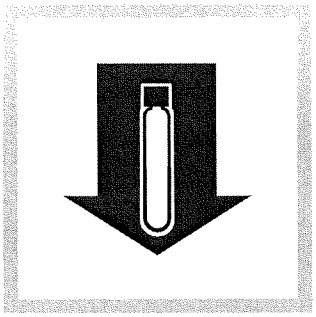


8. Touch the timer icon.

Touch **OK**.

A five-minute reaction period will begin. Do not invert the vial again.

A yellow color will develop if nitrate is present.



9. **Within five minutes** after the timer beeps, wipe the prepared sample and place it into the cell holder. Results will appear in mg/L NO_3^-–N.

Interferences

Interfering Substance	Interference Levels and Treatment
Barium	A negative interference at concentrations greater than 1 mg/L.
Chloride	Does not interfere below 1000 mg/L.
Nitrite	A positive interference at concentrations greater than 12 mg/L. Remove nitrite interference up to 100 mg/L by adding 400 mg (one full 0.5 g Hach measuring spoon) of Urea (Cat. No. 11237-26) to 10 mL of sample. Swirl to dissolve. Proceed with the nitrate test as usual.
Copper	Positive at all levels.

Sample Collection, Preservation, and Storage

Collect samples in clean plastic or glass bottles. Store at 4 °C (39 °F) or lower if the sample is to be analyzed within 24 to 48 hours. Warm to room temperature before running the test. For longer storage periods (up to 14 days), adjust sample pH to 2 or less with Concentrated Sulfuric Acid, ACS (about 2 mL per liter) (Cat. No. 979-49). Sample refrigeration is still required.

Before testing the stored sample, warm to room temperature and neutralize with 5.0 N Sodium Hydroxide Standard Solution (Cat. No. 2450-26).

Do not use mercury compounds as preservatives.

Correct the test result for volume additions; see *Section 3.1.3 Correcting for Volume Additions* on page *43*.

Accuracy Check

Standard Additions Method (Sample Spike)

1. After reading test results, leave the sample cell (unspiked sample) in the instrument. Verify the chemical form.
2. Touch **Options**. Touch **Standard Additions**. A summary of the standard additions procedure will appear.
3. Touch **OK** to accept the default values for standard concentration, sample volume, and spike volumes. Touch **Edit** to change these values. After values are accepted, the unspiked sample reading will appear in the top row. See *Standard Additions* in the instrument manual for more information.
4. Snap the neck off a High Range Nitrate Nitrogen Voluette® Ampule Standard, 500 mg/L NO_3^-–N.
5. Prepare three sample spikes. Fill three mixing cylinders (Cat. No. 1896-40) with 25 mL of sample. Use the TenSette® Pipet to add 0.1 mL, 0.2 mL, and 0.3 mL of standard, respectively, to each sample and mix thoroughly.
6. Analyze each sample spike as described in the procedure above, starting with the 0.1 mL sample spike. Accept each standard additions reading by touching **Read**. Each addition should reflect approximately 100% recovery.
7. After completing the sequence, touch **Graph** to view the best-fit line through the standard additions data points, accounting for matrix interferences. Touch **View: Fit**, then select **Ideal Line** and touch **OK** to view the relationship between the sample spikes and the "Ideal Line" of 100% recovery.

See *Section 3.2.2 Standard Additions* on page *46* for more information.

Standard Solution Method

Use a 10.0-mg/L Nitrate Nitrogen Standard Solution to check test accuracy.

See *Section 3.2.1 Standard Solutions* on page *45* for more information.

Method Performance

Precision

Standard: 10.0 mg/L NO_3^-–N

Program	95% Confidence Limits of Distribution
344	9.5–10.5 mg/L NO_3^-–N

See *Section 3.4.3 Precision* on page *53* for more information, or if the standard concentration did not fall within the specified range.

Sensitivity

Portion of Curve	ΔAbs	ΔConcentration
Entire range	0.010	0.2 mg/L NO_3^-–N

See *Section 3.4.5 Sensitivity* on page *54* for more information.

Summary of Method

Nitrate in the sample reacts with chromotropic acid under strongly acidic conditions to yield a yellow product with a maximum absorbance at 410 nm.

Required Reagents

Description	Quantity Required Per Test	Unit	Cat. No.
Test 'N Tube NitraVer® X Nitrate Reagent Set (50 tests)			26053-45

Required Apparatus

Funnel, micro, poly	1	each	25843-35
Pipet, TenSette®, 0.1 to 1.0 mL	1	each	19700-01
Pipet Tips, for 19700-01 TenSette® Pipet	varies	50/pkg	21856-96
Sample Cells, 10-mL, w/cap	2	6/pkg	24276-06
Test Tube Rack, cooling	1–3	each	18641-00

Required Standards

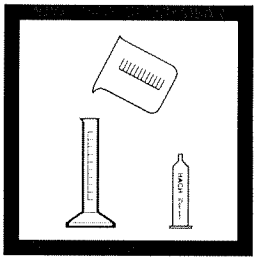
Nitrate Nitrogen Standard Solution, 10-mg/L N		500 mL	307-49
Nitrate Nitrogen Standard Solution, Voluette® Ampule, 500-mg/L N		16/pkg	14260-10
Water, deionized		4 liters	272-56

FOR TECHNICAL ASSISTANCE, PRICE INFORMATION AND ORDERING:
In the U.S.A. – **Call toll-free 800-227-4224**
Outside the U.S.A. – **Contact the HACH office or distributor serving you.**
On the Worldwide Web – **www.hach.com**; E-mail – **techhelp@hach.com**

HACH COMPANY
WORLD HEADQUARTERS
Telephone: (970) 669-3050
FAX: (970) 669-2932

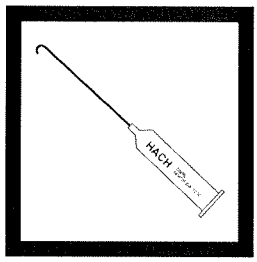
ALKALINITY (10 to 4000 mg/L as $CaCO_3$)

Phenolphthalein and Total Method

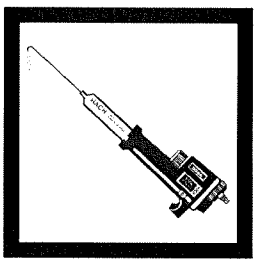


1. Select the sample volume and Sulfuric Acid (H_2SO_4) Titration Cartridge corresponding to the expected alkalinity concentration as mg/L calcium carbonate ($CaCO_3$) from *Table 1*.

Note: *See Sampling and Storage following these steps.*

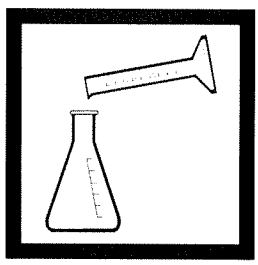


2. Insert a clean delivery tube into the titration cartridge. Attach the cartridge to the titrator body. See *General Description, Step-by-Step* for assembly instructions, if necessary.



3. Turn the delivery knob to eject a few drops of titrant. Reset the counter to zero and wipe the tip.

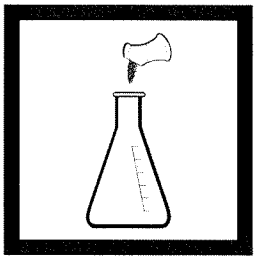
Note: *For added convenience use the TitraStir® Stir Plate. See General Description, Step 3 in Step-by-Step.*



4. Use a graduated cylinder or pipet to measure the sample volume from *Table 1*. Transfer the sample into a clean 250-mL Erlenmeyer flask. Dilute to about the 100-mL mark with deionized water, if necessary.

Table 1

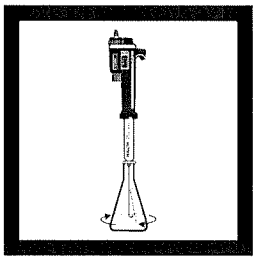
Range (mg/L as $CaCO_3$)	Sample Volume (mL)	Titration Cartridge (H_2SO_4)	Catalog Number	Digit Multiplier
10-40	100	0.1600	14388-01	0.1
40-160	25	0.1600	14388-01	0.4
100-400	100	1.600	14389-01	1.0
200-800	50	1.600	14389-01	2.0
500-2000	20	1.600	14389-01	5.0
1000-4000	10	1.600	14389-01	10.0



5. Add the contents of one Phenolphthalein Indicator Powder Pillow and swirl to mix.

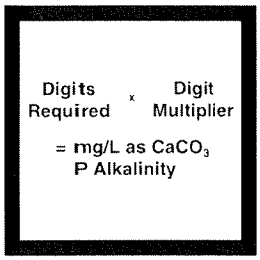
Note: *A solution of one pH 8.3 Buffer Powder Pillow and one Phenolphthalein Powder Pillow in 50 mL of deionized water is recommended as a comparison for determining the proper end point color.*

Note: *Four drops of Phenolphthalein Indicator Solution may be substituted for the Phenolphthalein Indicator Powder Pillow.*



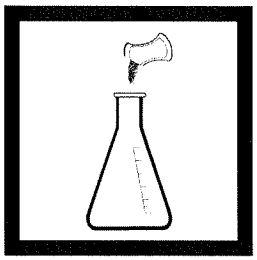
6. If the solution turns pink, titrate to a colorless end point. Place the delivery tube tip into the solution and swirl the flask while titrating with sulfuric acid. Record the number of digits required.

Note: *If the solution is colorless before titrating with sulfuric acid, the Phenolphthalein (P) Alkalinity is zero; proceed with step 8.*



7. Calculate:

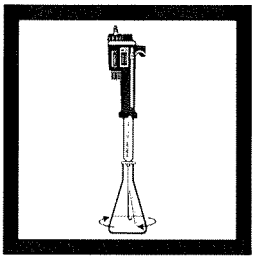
Digits Required x Digit Multiplier = mg/L $CaCO_3$ P Alkalinity



8. Add the contents of one Bromcresol Green-Methyl Red Indicator Powder Pillow to the flask and swirl to mix.

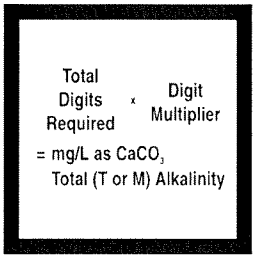
Note: *Four drops of Methyl Purple Indicator Solution may be substituted for the Bromcresol Green-Methyl Red Indicator Powder Pillow. Titrate from green to a gray end point (pH 5.1).*

Note: *Four drops of Bromcresol Green-Methyl Red Indicator Solution may be substituted for the Bromcresol Green-Methyl Red Indicator Powder Pillow.*



9. Continue the titration with sulfuric acid to a light greenish blue-gray (pH 5.1), a light violet-gray (pH 4.8), or a light pink (pH 4.5) color, as required by the sample composition; see *Table 2*. Record the number of digits required.

***Note:** A solution of one Bromcresol Green-Methyl Red Powder Pillow and one pillow of the appropriate pH buffer in 50 mL of deionized water is recommended as a comparison for judging the proper end point color. If the pH 3.7 end point is used, use a Bromphenol Blue Powder Pillow instead of a Bromcresol Green-Methyl Red and titrate to a green end point.*



10. Calculate:

Total Digits Required x Digit Multiplier = mg/L as CaCO3 Total (T or M) Alkalinity

***Note:** Carbonate, bicarbonate and hydroxide concentrations may be expressed individually using the relationships shown in Table 3.*

***Note:** meq/L Alkalinity = mg/L as $CaCO_3$ ÷ 50.*

Table 2

Sample Composition	End Point
Alkalinity about 30 mg/L	pH 4.9
Alkalinity about 150 mg/L	pH 4.6
Alkalinity about 500 mg/L	pH 4.3
Silicates or Phosphates present	pH 4.5
Industrial waste or complex system	pH 4.5

Sampling and Storage

Collect samples in clean plastic or glass bottles. Fill completely and cap tightly. Avoid excessive agitation or prolonged exposure to air. Samples should be analyzed as soon as possible after collection but can be stored at least 24 hours by cooling to 4 °C (39 °F) or below. Warm to room temperature before analyzing.

Alkalinity Relationship Table

Total alkalinity primarily includes hydroxide, carbonate and bicarbonate alkalinities. The concentration of these alkalinities in a sample may be determined when the phenolphthalein and total alkalinities are known (see *Table 3*).

Table 3 Alkalinity Relationship

Row	Result of Titration	Hydroxide Alkalinity is equal to:	Carbonate Alkalinity is equal to:	Bicarbonate Alkalinity is equal to:
1	Phenolphthalein Alkalinity = 0	0	0	Total Alkalinity
2	Phenolphthalein Alkalinity equal to Total Alkalinity	Total Alkalinity	0	0
3	Phenolphthalein Alkalinity less than one half of Total Alkalinity	0	2 times the Phenolphthalein Alkalinity	Total Alkalinity minus two times Phenolphthalein Alkalinity
4	Phenolphthalein Alkalinity equal to one half of Total Alkalinity	0	Total Alkalinity	0
5	Phenolphthalein Alkalinity greater than one half of Total Alkalinity	2 times the Phenolphthalein minus Total Alkalinity	2 times the difference between Total and Phenolphthalein Alkalinity	0

To use the table follow these steps:

a. Does the phenolphthalein alkalinity equal zero? If yes, use Row 1.

b. Does the phenolphthalein alkalinity equal total alkalinity? If yes, use Row 2.

c. Multiply the phenolphthalein alkalinity by 2.

d. Select Row 3, 4, or 5 based on comparing the result of *step c* with the total alkalinity.

e. Perform the required calculations in the appropriate row, if any.

f. Check your results. The sum of the three alkalinity types will equal the total alkalinity.

For example:
A sample has 170 mg/L as $CaCO_3$ phenolphthalein alkalinity and 250 mg/L as $CaCO_3$ total alkalinity. What is the concentration of hydroxide, carbonate and bicarbonate alkalinities?

The phenolphthalein alkalinity does not equal 0 (it is 170 mg/L), see *step a*.

The phenolphthalein alkalinity does not equal total alkalinity (170 mg/L vs. 250 mg/L), see *step b*.

The phenolphthalein alkalinity multiplied by 2 = 340 mg/L, see *step c*.

Because 340 mg/L is greater than 250 mg/L, select Row 5, see *step d*.

The hydroxide alkalinity is equal to: (see *step e*).

340 – 250 = 90 mg/L hydroxide alkalinity

The carbonate alkalinity is equal to:

250 – 170 = 80
80 x 2 = 160 mg/L carbonate alkalinity

The bicarbonate alkalinity equals 0 mg/L.

Check: (see *step f*).

90 mg/L hydroxide alkalinity + 160 mg/L carbonate alkalinity +
0 mg/L bicarbonate alkalinity = 250 mg/L

The above answer is correct; the sum of each type equals the total alkalinity.

Accuracy Check

Standard Additions Method
This accuracy check should be performed when interferences are suspected or to verify analytical technique.

1. Snap the neck off an Alkalinity Standard Solution Voluette® Ampule, 0.500 N.
2. Use a TenSette® Pipet to add 0.1 mL of standard to the sample titrated in Steps 6 or 9. Resume titration back to the same end point. Record the number of digits needed.
3. Repeat, using two more additions of 0.1 mL. Titrate to the end point after each addition.
4. Each 0.1 mL addition of standard should require 25 additional digits of 1.600 N titrant or 250 digits of 0.1600 N titrant. If these uniform increases do not occur, refer to *Appendix A, Accuracy Check and Standard Additions.*

Interferences

- Highly colored or turbid samples may mask the color change at the end point. Use a pH meter for these samples.
- Chlorine may interfere with the indicators. Add one drop of 0.1 N Sodium Thiosulfate to eliminate this interference.

Summary of Method

The sample is titrated with sulfuric acid to a colorimetric end point corresponding to a specific pH. Phenolphthalein alkalinity is determined by titration to a pH of 8.3, as evidenced by the color change of phenolphthalein indicator, and indicates the total hydroxide and one half the carbonate present. M (methyl orange) or T (total) alkalinity is determined by titration to a pH between 3.7 and 5.1, and includes all carbonate, bicarbonate and hydroxide.

REQUIRED REAGENTS
(varies with sample characteristics)

Description	Unit	Cat. No
Alkalinity Reagent Set (about 100 tests)		22719-00
Includes: (1) 942-99, (1) 943-99, (1) 14388-01, (1) 14389-01		
Bromcresol Green-Methyl Red Powder Pillows	100/pkg	943-99
Phenolphthalein Powder Pillows	100/pkg	942-99
Sulfuric Acid Titration Cartridge, 1.600 N	each	14389-01
Sulfuric Acid Titration Cartridge, 0.1600 N	each	14388-01
Water, deionized	4 L	272-56

REQUIRED APPARATUS

Digital Titrator	each	16900-01
Flask, Erlenmeyer, 250-mL	each	505-46
Select one or more based on sample concentration:		
Cylinder, graduated, 10-mL	each	508-38
Cylinder, graduated, 25-mL	each	508-40
Cylinder, graduated, 50-mL	each	508-41
Cylinder, graduated, 100-mL	each	508-42

OPTIONAL REAGENTS

Alkalinity Standard Solution Voluette® Ampules, 0.500 N Na_2CO_3, 10-mL	16/pkg	14278-10
Bromcresol Green-Methyl Red Indicator Solution	100 mL MDB	23292-32
Bromphenol Blue Indicator Solution	100 mL MDB	14552-32
Bromphenol Blue Powder Pillows	100/pkg	14550-99
Buffer Powder Pillows, pH 3.7	25/pkg	14551-68
Buffer Powder Pillows, pH 4.5	25/pkg	895-68
Buffer Powder Pillows, pH 4.8	25/pkg	896-68
Buffer Powder Pillows, pH 5.1	25/pkg	897-68
Buffer Powder Pillows, pH 8.3	25/pkg	898-68
Methyl Purple Indicator Solution	100 mL MDB	21934-32
Phenolphthalein Indicator Solution, 5 g/L	100 mL MDB*	162-32
Sodium Thiosulfate Standard Solution, 0.1 N	100 mL MDB	323-32

* Contact Hach for larger sizes.

OPTIONAL APPARATUS

Description	Unit	Cat. No
Bottle, wash, poly, 500-mL	each	620-11
Clamp, 2-prong extension, 38-mm	each	21145-00
Clamp Holder	each	326-00
Demineralizer Assembly, 473-mL	each	21846-00
Delivery Tubes, with 180° hook	5/pkg	17205-00
Delivery Tubes, 90° with hook for TitraStir® Stir Plate	5/pkg	41578-00
Pipet, TenSette® 0.1 to 1.0 mL	each	19700-01
Pipet Tips for 19700-01 TenSette® Pipet	50/pkg	21856-96
Pipet, volumetric, Class A, 10-mL	each	14515-38
Pipet, volumetric, Class A, 20-mL	each	14515-20
Pipet, volumetric, Class A, 25-mL	each	14515-40
Pipet, volumetric, Class A, 50-mL	each	14515-41
Pipet, volumetric, Class A, 100-mL	each	14515-42
Pipet Filler, safety bulb	each	14651-00
sension™*1* Basic Portable pH Meter with electrode	each	51700-10
Support Ring Stand	each	563-00
TitraStir® Stir Plate, 115 Vac	each	19400-00
TitraStir® Stir Plate, 230 Vac	each	19400-10
Voluette® Ampule Breaker Kit	each	21968-00

3.1 Sample Collection, Preservation, and Storage

Correct sampling and storage are critical for accurate testing. Sampling devices and containers must be thoroughly clean to prevent carryover from previous samples. Preserve the sample properly; each procedure has information about sample preservation.

3.1.1 Collecting Water Samples

Use a clean container. Rinse the container several times with the water to be sampled before taking the sample. Document the location and procedure used for each sample taken. For example:

From a tap Take samples as close as possible to the source of the supply. This lessens the influence of the distribution system on the sample. Let the water run long enough to flush the system. Fill sample containers slowly with a gentle stream to avoid turbulence and air bubbles.

When testing well water, let the pump run long enough to draw fresh groundwater into the system. Collect a sample from a tap near the well.

From open waters Sample as near the middle of the body of water as is practical; at least several feet from the shore or edge of the tank.

Take the sample under the surface of the water. If you are using a capped container, submerge it before removing the cap.

3.1.1.1 Types of Containers

Table 1 lists recommended containers for specific parameters.

- **Polypropylene and Polyethylene** — These are the least expensive containers.
- **Quartz or TFE (tetrafluoroethylene, Teflon®)**—These are the best, and the most expensive.
- **Glass**—Glass provides a good general-purpose container. Avoid using soft-glass containers to collect samples to be tested for metals in the microgram-per-liter range.

  When determining silver, store samples in dark containers such as amber or brown glass.

Acid washing will thoroughly clean sample containers before use.

3.1.1.2 Acid Washing

If a procedure suggests acid washing, follow these steps:

a. Clean the glassware or plasticware with laboratory detergent. Phosphate-free detergent is best. (When determining phosphates, phosphate-free detergent *must* be used.)
b. Rinse well with tap water.
c. Rinse with a 1:1 hydrochloric acid solution or a 1:1 nitric acid solution. (Nitric acid is best when testing for lead or other metals.)
d. Rinse well with deionized water. For chromium, 12–15 rinses may be necessary. When determining ammonia and Kjeldahl nitrogen, the rinse water must be ammonia-free.

e. Air dry. Protect the glassware from fumes and other sources of contamination when storing.

Use chromic acid or chromium-free substitutes to remove organic deposits from glass containers. Afterward, rinse thoroughly with water to remove all traces of chromium.

Avoid introducing metal contaminants from containers, distilled water, or membrane filters.

3.1.1.3 Sample Splits

Samples must often be split or divided into separate containers for intra- or inter-laboratory use in studies, confirmation, alternative techniques, or maintaining additional sample for reference, or stability studies. It is very important that sample splits be done correctly.

- Collect a large volume of sample in a single container and transfer to smaller containers; do not fill the smaller containers individually from the water source.
- Thoroughly mix samples containing particulates or solids before splitting so that all the splits are homogeneous.
- If the sample requires filtering before analysis or storage, filter the entire sample before splitting.
- Use the same kind of container for all the splits.
- Analyze biologically active splits on the same day, or as close to the same day as is possible.
- Preserve all splits in the same way; if this is not done, the differing methods must be fully documented.
- When testing for volatile contaminants, fill containers samples to overflowing and cap carefully. Do not leave any headspace or air in the container.

3.1.2 Storage and Preservation

Because chemical and biological processes continue after collection, analyze the sample as soon as possible. This also reduces the chance for error and minimizes labor. When immediate analysis is not possible, the sample must be preserved. Preservation methods include pH control, chemical addition, refrigeration, and freezing.

Table 1 presents an overview of preservation methods and holding times for specific procedures.

You can preserve aluminum, cadmium, chromium, cobalt, copper, iron, lead, nickel, potassium, silver, and zinc samples for at least 24 hours by adding one Nitric Acid Solution Pillow 1:1 (Cat. No. 2540-98) per liter of sample. Check the pH with pH indicator paper or a pH meter to assure the pH is 2 or less. Add additional pillows if necessary. Adjust the sample pH prior to analysis by raising the pH to 4.5 with Sodium Hydroxide Standard Solution, 1 N or 5 N.

3.1.3 Correcting for Volume Additions

If you use a large volume of preservative or neutralizer, you must account for dilution by the acid added to preserve the sample, and/or the base used to adjust the pH to the range of the procedure. Make this correction as follows:

1. Determine the volume of initial sample, the volume of acid and base added, and the total final volume of the sample.
2. Divide the total volume by the initial volume.
3. Multiply the test result by this factor.

Example:

A one-liter sample was preserved with 2 mL of nitric acid. It was neutralized with 5 mL of 5 N sodium hydroxide. The result of the analysis procedure was 10.00 mg/L. What is the volume correction factor and correct result?

1. Total Volume = 1000 mL + 2 mL + 5 mL = 1007 mL
2. $\frac{1007}{1000}$ = 1.007 = volume correction factor
3. 10.0 mg/L × 1.007 = 10.07 mg/L = correct result

Hach 1:1 Nitric Acid Pillows contain 2.5 mL of acid: correct for this volume.

Table 1 Required Containers, Preservation Techniques and Holding Times*

Parameter Name	Container**	Preservation***,****	Maximum Holding Time*****
Table 1A - Bacterial Tests			
Coliform, fecal and total	P,G	Cool, 4 °C, 0.008% $Na_2S_2O_3$	6 hours
Fecal streptococci	P,G	Cool, 4 °C, 0.008% $Na_2S_2O_3$	6 hours
Table 1A - Aquatic Toxicity Tests			
Toxicity, acute and chronic	P, G	Cool, 4 °C	36 hours
Table 1B - Chemical Tests			
Acidity	P, G	Cool, 4 °C	14 days
Alkalinity	P, G	Cool, 4 °C	14 days
Ammonia	P, G	Cool, 4 °C, H_2SO_4 to pH<2	28 days
Biochemical oxygen demand (BOD)	P, G	Cool, 4 °C	48 hours
Boron	P, PFTE or quartz	HNO_3 to pH<2	6 months
Bromide	P, G	None required	28 days
Biochemical oxygen demand, carbonaceous	P, G	Cool, 4 °C	48 hours
Chemical oxygen demand	P, G	Cool, 4 °C, H_2SO_4 to pH<2	28 days
Chloride	P, G	None required	28 days
Chlorine, total residual	P, G	None required	Analyze immediately
Color	P, G	Cool, 4 °C	48 hours
Cyanide, total and amenable to chlorination	P, G	Cool, 4 °C, NaOH to pH>12, 0.6 g ascorbic acid******	14 days*******
Fluoride	P	None required	28 days
Hardness	P, G	HNO_3 to pH<2, H_2SO_4 to pH<2	6 months

Table 1 Required Containers, Preservation Techniques and Holding Times* (continued)

Parameter Name	Container**	Preservation***[1] [2] [3]	Maximum Holding Time***[4]
Hydrogen ion (pH)	P, G	None required	Analyze immediately
Kjeldahl and organic nitrogen	P, G	Cool 4 °C, H_2SO_4 to pH<2	28 days
Metals[7]			
Chromium VI	P, G	Cool, 4 °C	24 hours
Mercury	P, G	HNO_3 to pH<2	28 days
Metals, except boron, chromium VI and mercury	P, G	HNO_3 to pH<2	6 months
Nitrate	P, G	Cool, 4 °C	48 hours
Nitrate-nitrite	P, G	Cool 4 °C, H_2SO_4 to pH<2	28 days
Nitrite	P, G	Cool, 4 °C	48 hours
Oil and grease	G	Cool, 4 °C, HCl or H_2SO_4 to pH<2	28 days
Organic Carbon	P, G	Cool, 4 °C, HCl or H_2SO_4 or H_3PO_4 to pH<2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4 °C	48 hours
Oxygen, dissolved probe	G Bottle and top	None required	Analyze immediately
Oxygen, Winkler	G Bottle and top	Fix on site and store in dark	8 hours
48. Phenols	G only	Cool 4 °C, H_2SO_4 to pH<2	28 days
Phosphorus, elemental	G	Cool, 4 °C	48 hours
Phosphorus, total	P, G	Cool, 4 °C, H_2SO_4 to pH<2	28 days
Residue, Total	P, G	Cool, 4 °C	7 days
Residue, Filterable	P, G	Cool, 4 °C	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4 °C	7 days
Residue, Settleable	P, G	Cool, 4 °C	48 hours
Residue, Volatile	P, G	Cool, 4 °C	7 days
Silica	P, PFTE or quartz	Cool, 4 °C	28 days
Specific Conductance	P, G	Cool, 4 °C	28 days
Sulfate	P, G	Cool, 4 °C	28 days
Sulfide	P, G	Cool 4 °C, add zinc acetate plus sodium hydroxide to pH>9	7 days
Sulfite	P, G	none required	Analyze immediately
Surfactants	P, G	Cool, 4 °C	48 hours
Temperature	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4 °C	48 hours

* This table was adapted from Table II in the *Code of Federal Regulations*, July 1, 2000, Title 40, Part 136.3 (40 CFR 136.3), pages 23–25. Most organic tests are not included.

** Polyethylene (P) or glass (G), or PTFE Teflon

***Sample preservation should be performed immediately upon sample collection. For composite chemical samples each portion should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each portion, then chemical samples may be preserved by maintaining at 4 °C until compositing and sample splitting is completed.

****When any sample is to be shipped by common carrier or sent through United States Mails, it must comply with the *Department of Transportation Hazardous Material Regulations* (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

*****Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory has data on file to show that the specific types of samples under study are stable for the longer time, and has received a variance from the Regional Administrator under §136.3(e). Some samples may not be stable for the maximum time period given in the table. A permittee or monitoring laboratory is obligated to hold the sample for a shorter time if knowledge exists to show that this is necessary to maintain sample stability. See §136.3(e) for details. The term "analyze immediately" usually means within 15 minutes or less after sample collection.

******Should only be used in the presence of residual chlorine.

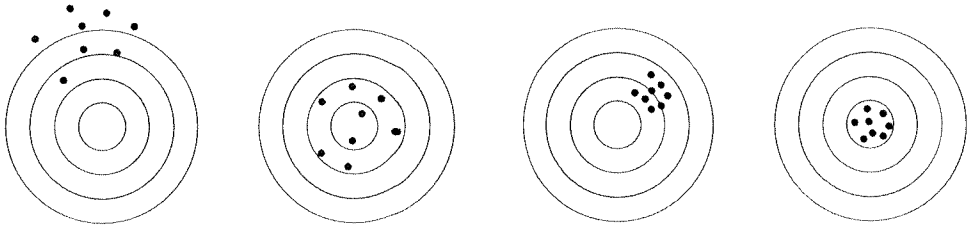
*******Maximum holding time is 24 hours when sulfide is present. Optionally all samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

********Samples should be filtered immediately on-site before adding preservative for dissolved metals.

3.2 Checking for Accuracy and Precision

Accuracy defines the closeness of a test result to the true value. Precision defines the closeness of repeated measurements to each other. Although precise results suggest accuracy, they can be inaccurate. Both the accuracy and the precision of test results can be evaluated by using standard additions or standard solutions.

Figure 1 Precision and Accuracy Illustrated



3.2.1 Standard Solutions

A standard solution may be ordered as a prepared reagent or it may be made in the laboratory. It is a solution of a known composition and concentration. The accuracy of your analysis system may be checked by using a standard solution in place of the sample water in a procedure.

3.2.2 Standard Additions

Standard Additions is a common technique for checking test results. Other names are "spiking" and "known additions." The technique can test for interferences, bad reagents, faulty instruments, and incorrect procedures.

Perform Standard Additions by adding a small amount of a standard solution to your sample and repeating the test. Use the same reagents, equipment, and technique. You should get about 100% recovery. If not, you have an identifiable problem.

If Standard Additions works for your test, a Standard Additions Method section will be in the procedure under Accuracy Check. Follow the detailed instructions given.

If you get about 100% recovery for each addition, everything is working properly and your results are correct.

If you don't get about 100% recovery for each addition, a problem exists. You can tell if you have an interference. Repeat the Standard Additions using deionized water as your sample. If you get about 100% recovery for each addition, you have an interference.

If you didn't get good recoveries with the deionized water, use the following checklist to find the problem:

1. Check to see that you are following the procedure exactly:
   a. Are you using the proper reagents in the proper order?
   b. Are you waiting the necessary time for color to develop?
   c. Are you using the correct glassware?
   d. Is the glassware clean?
   e. Does the test need a specific sample temperature?
   f. Is the sample's pH in the correct range?

Hach's written procedure should help you to answer these questions.

2. Check the performance of your instrument. Follow the instructions in the Service Checks section of the instrument manual.
3. Check your reagents. Repeat the Standard Additions using new, fresh reagents. If your results are good, the original reagents were faulty.
4. If nothing else is wrong, the standard is almost certainly defective. Repeat the Standard Additions with a new standard.
5. If you still cannot identify the problem, you may need some extra help. Please call Hach's Technical Support Group at 800-227-4224 (U.S.A.) or 303-669-3050. A representative will be happy to help you.

3.2.3 Troubleshooting a Test When Results are in Doubt

If the results from any Hach chemistry are in doubt, troubleshoot them as follows:

1. Run a proof-of-accuracy check. Take a standard solution, which has a known concentration, through the same steps as the original sample. Include sampling and storage, digestion and colorimetric determination, if applicable. If the results of the standard solution check are correct, skip to *step 4* below. If there is a variation in the expected results, go to *step 2.*

2. If the standard solutions check does not match the expected results, check the instrument set-up and method procedure as follows:
   a. Verify that the correct program number for the test being performed is selected.
   b. Verify that the units of concentration of the standard match the displayed units. (One of the alternative forms of the analyte may be in the display.) For example: Molybdenum may be shown as Mo instead of MoO_4.
   c. Verify that the sample cells called for in the procedure are the ones being used.
   d. Verify that the reagents are correct for the sample size being analyzed.
   e. Where applicable, verify that the reagent blank value stored is for the current procedure. It may be from a previous lot of reagents and therefore not representative of the current reagent lot.
   f. Where applicable, verify the calibration curve adjustment (Standard Adjust) currently in use. The factory-stored default calibration should be used initially to check the standard.
   g. Where applicable, verify that the dilution factor option is correct.

If the instrument setup is correct and the method procedure specifics are being followed correctly, go to *step 3.*

3. If the standard solution check does not match the expected results, check the reagents used in the test and the analytical technique as follows:
   a. Determine the age of the reagents used in the test. While most Hach reagents have a long shelf life, many factors affect this (i.e., storage temperature, storage conditions, microbial contamination). Replace suspect reagents and run the standards check again.
   b. Run a deionized or distilled water blank through the entire process; include sampling and storage, digestion, and colorimetric determination. Some chemicals will add a small amount of color to a test; this is not considered unusual. However, color development in excess of 10% of the range of the test may indicate a problem with one of the reagents or the dilution water.
   c. To troubleshoot the procedure, delete the parts one by one. First, using the standard solution, omit preservation and storage, doing only digestion and colorimetry. If this analysis is correct, examine the procedure used to store the sample. Ensure that it is the procedure prescribed for the chosen parameter. If the sample is acidified for storage, be sure the correct acid is used and the sample is adjusted to the proper pH level before testing.

      If the standards check is still incorrect, run the standard on just the colorimetry. If the results are correct, examine the digestion procedure. Ensure that the amount of reagents used and the pH after the digestion are correct for the procedure. (See the procedure for the parameter in question.)

4. If the standard solution gives a correct value, but the results of the sample measurement are questionable, there may be an interference in the sample. To check for an interference:
   a. Spike the sample. Use a standard addition test instead of a standard solution test to include any possible interferences.

To two cells containing fresh sample water, add an amount of standard equal to two times the concentration of the sample. Process both samples using the same reagents, instruments, and technique. The spiked sample should show an increase equal to the amount of standard added. Calculate percent recovery as shown below. Ideally, the results should be 100%, with results from 90 to 110% considered acceptable. Refer to the procedure notes for possible interferences and ways to eliminate them.

b. Run a series of dilutions on the sample. Make sure your sample is within the range of the test. A sample out of range for the method may give erroneous results because of under- or over-development of the color, excess turbidity, or even sample bleaching. Run a series of dilutions to check for this possibility.

   Because it may not be feasible to determine the cause of the interference, diluting the sample past the point of interference is often the most economical and efficient means of getting the correct result. If it is not possible to dilute out an interference without diluting out the parameter to be measured, use a different method, such as a different chemistry or an ion-selective electrode to measure the parameter.

Calculating percent recovery:

1. Measure the unknown sample concentration.
2. Calculate the theoretical concentration of the spiked sample using the following formula:

$$\text{Theoretical Concentration} = \frac{(C_u \times V_u) + (C_s \times V_s)}{V_u + V_s}$$

Where:

C_u = measured concentration of the unknown sample
V_u = volume of the unknown sample
C_s = concentration of the standard
V_s = volume of the standard

3. Measure the spiked sample concentration.
4. Divide the spiked sample concentration by the theoretical concentration and multiply by 100.

For example:

A sample was tested for manganese and the result was 4.5 mg/L. A separate 97-mL portion of the same sample was spiked with 3 mL of a 100 mg/L standard solution of manganese. This spiked solution was tested again for manganese using the same method. The result was 7.1 mg/L.

The theoretical concentration of the spiked sample is:

$$\frac{(4.5\ \text{mg/L} \times 97\ \text{mL}) + (100\ \text{mg/L} \times 3\ \text{mL})}{97\ \text{mL} + 3\ \text{mL}} = 7.4\ \text{mg/L}$$

The percent spike recovery is:

$$\frac{7.1\ \text{mg/L}}{7.4\ \text{mg/L}} \times 100 = 96\%$$

USEPA Calculation

The USEPA requires a more stringent calculation for percent recovery. This formula calculates the percent recovery only for the standard added to the spiked sample and yields a lower value than the above calculation. A complete

explanation for the USEPA formula is in *USEPA Publication SW-846*. The USEPA percent recovery formula is:

$$\%R = \frac{100(X_s - X_u)}{K}$$

Where:

X_s = measured value of the spiked sample
X_u = measured value for the unspiked sample, adjusted for the dilution of the spike volume
K = known value of the spike in the sample

Example:

A sample measures 10 mg/L. A separate 100-mL portion of the sample was spiked with 5 mL of a 100-mg/L standard solution. The spiked solution was measured by the same method as the original sample. The result was 13.7 mg/L.

X_s = 13.7 mg/L

$$X_u = \frac{10\ mg/L \times 100\ mL}{105\ mL} = 9.5\ mg/L$$

$$K = \frac{5\ mL \times 100\ mg/L}{105\ mL} = 4.8\ mg/L$$

$$\%R = \frac{100 \times (13.7\ mg/L - 9.5\ mg/L)}{4.8\ mg/L} = 88\%$$

Acceptable percent recovery values are 80-120%.

3.2.4 Adjusting the Standard Curve

Note: *Not available on all instruments.*

Hach instruments contain programs permanently installed in memory. A program usually includes a pre-programmed calibration curve. Each curve is the result of an extensive calibration performed under ideal conditions and is normally adequate for most testing. Deviations from the curve can occur from using compromised testing reagents, defective sample cells, incorrect test procedure, incorrect technique, or other correctable causes. Interfering substances or other causes may be beyond the analyst's control.

In some situations, using the pre-programmed curve may not be convenient:

- Running tests where the reagents are highly variable from lot to lot.
- Running tests where frequent calibration curve checks are required.
- Testing samples which give a consistent test interference.

Consider the following before adjusting the calibration curve:

- Will future test results be improved by adjusting the curve?
- Are interfering substances consistent in all the samples that you will test?
- Any estimated detection limit, sensitivity, precision, and test range information provided with the procedure may not apply to an adjusted curve calibration.

The calibration curves can be adjusted by following the steps found in the test procedure. Generally, you add test reagents to a blank and standard solution. Working carefully is important. After the adjustment, it is wise to run standard solutions of several concentrations to make sure the adjusted curve is

satisfactory. Performing standard additions on typical samples may also help determine if the adjusted curve is acceptable.

Think of adjusting a measurement as a two-step process. First, the instrument measures the sample using the pre-programmed calibration. Second, it multiplies this measurement by an adjustment factor. The factor is the same for all concentrations The instrument will remember the factor until the program is exited and will display the standard adjustment icon when it is used. You can return to the pre-programmed curve any time by selecting the Hach Program from the main menu.

3.3 Interferences

Interferences are contaminants in a sample that are capable of causing changes in color development, turbidity, or unusual colors and odors, thereby creating errors in your results. A list of common interferences is included in each procedure. Hach reagents are formulated to eliminate many interferences; you can remove others by pretreating the sample as instructed in the procedure.

Test strips are available for many of the common interferences. These can be conveniently used to screen samples for the presence of interferences.

If you get test results that you feel are inaccurate, if you get an unexpected color, or if you notice an unusual odor or turbidity, repeat the test on a sample diluted with deionized water. (See *Section 2.7 Sample Dilution.*) Correct the results for the dilution, and compare them with those from your original test. If they differ significantly, make a second dilution and check it against the first. Repeat the dilutions until you get the same result (after volume corrections) twice in succession.

For more information on interferences, see *Section 3.2.2 Standard Additions.* The *APHA Standard Methods* book, an excellent reference for the water analyst, also covers interferences in its "General Introduction."

pH Interference

Chemical reactions are often pH dependent. Hach reagents contain buffers to adjust the pH of the sample to the correct range. However, the reagent buffer may not be strong enough for samples that are highly buffered or have an extreme pH.

The *Sampling and Storage* section of each procedure gives the pH range for that test.

Before testing, adjust the sample to the proper pH as instructed in the procedure, or by following these steps:

1. Measure the pH of your analyzed sample with a pH meter.

   Note: *Use pH paper when testing for chloride, potassium, or silver to avoid contamination.*

2. Prepare a reagent blank using deionized water as the sample. Add all reagents called for in the procedure. Timer sequences, etc., may be ignored. Mix well.
3. Measure the pH of the reagent blank with a pH meter.
4. Compare the pH values of your analyzed sample with the reagent blank.
5. If there is little difference in the values of your analyzed sample and the reagent blank, then pH interference is not the problem. Follow the *Accuracy Check* for the specific procedure to more clearly identify the problem.

6. If there is a large difference between the value of your analyzed sample and the reagent blank, adjust the sample pH to the value of the reagent blank. Adjust the sample pH to this same pH for all future samples before analysis. Use the appropriate acid, usually nitric acid, to lower the pH. Use the appropriate base, usually sodium hydroxide, to raise the pH. Adjust the final result for any dilution caused by adding acid or base; see *Correcting for Volume Additions.*
7. Analyze the sample as before.
8. Some purchased standards may be very acidic and will not work directly with Hach procedures. Adjust the pH of these standards as described above. Adjust the final concentration of the standard for the dilution. The Hach standard solutions suggested in the procedures are formulated so that no pH adjustment is necessary.

3.4 Method Performance

3.4.1 Estimated Detection Limit (EDL)

Ranges for chemical measurements have limits. The lower limit is important because it determines whether a measurement is different from zero. Many experts disagree about the definition of this detection limit, and determining it can be difficult. The *Code of Federal Regulations* (40 CFR, Part 136, Appendix B) provides a procedure to determine the "Method Detection Limit" or MDL. The MDL is the lowest concentration that is different from zero with a 99% level of confidence. A measurement below this MDL is highly suspect.

The MDL is not fixed; it varies for each reagent lot, instrument, analyst, sample type, etc. Therefore, a published MDL may be a useful guide, but is only accurate for a specific set of circumstances. Each analyst should determine a more accurate MDL for each specific sample matrix using the same equipment, reagents, and standards that will routinely be used for measurements.

Hach provides a sensitivity value (concentration change equivalent to an absorbance change of 0.010 abs) as an estimate of the lower detection limit of each test. The sensitivity value may be treated as an EDL for the purposes of MDL determination. It can be considered a good starting concentration when determining a MDL. **Do not use the EDL for MDL.** The conditions for MDL determination must be exactly the same as the conditions used for analysis. The EDL may be useful to the analyst as a starting point in determining a MDL, or as a way to compare methods. Measurements below the EDL may also be valuable because they can show a trend, indicate the presence of analyte and/or provide statistical data. However, these values have a large uncertainty.

3.4.2 Method Detection Limit (MDL)

This method is in accordance with the USEPA definition in 40 CFR, Part 136, Appendix B in the 7-1-94 edition. The USEPA defines the method detection limit (MDL) as the minimum concentration that can be determined with a 99% level of confidence that the true concentration is greater than zero. Since the MDL will vary from analyst to analyst, it is important that the MDL be determined under actual operating conditions.

The procedure for determining MDL is based on replicate analyses at a concentration 1 to 5 times the estimated detection limit. The MDL value is calculated from the standard deviation of the replicate study results multiplied by the appropriate Student's *t* value for a 99% confidence interval. For this

definition, the MDL does not account for variation in sample composition and can only be achieved under ideal conditions.

1. Estimate the detection limit. Use the Hach sensitivity value stated in the *Method Performance* section of the analysis procedure.
2. Prepare a laboratory standard of the analyte, 1 to 5 times the estimated detection limit, in deionized water that is free of the analyte.
3. Analyze at least seven portions of the laboratory standard and record each result.
4. Calculate the average and the standard deviation(*s*) of the results.
5. Compute the MDL using the appropriate Student's *t* value (see table below) and the standard deviation value:

MDL = Students t × s

Number of Test Portions	Student's *t* Value
7	3.143
8	2.998
9	2.896
10	2.821

For example:

The EDL for measuring iron using the FerroZine® method is 0.003 mg/L. An analyst accurately prepared 1 liter of a 0.010 mg/L (about 3x the EDL) laboratory standard by diluting a 10-mg/L iron standard in iron-free deionized water.

Eight portions of the standard were tested according to the FerroZine method with the following results:

Sample #	Result (mg/L)
1	0.009
2	0.010
3	0.009
4	0.010
5	0.008
6	0.011
7	0.010
8	0.009

Using a calculator program, the average concentration = 0.010 mg/L and the standard deviation (*s*) = 0.0009 mg/L

Based on the USEPA's definition, calculate the MDL as follows:

MDL for FerroZine method = 2.998 (Student's *t*) x 0.0009 (*s*)

MDL = 0.003 mg/L (agrees with initial estimate)

Note: *Occasionally, the calculated MDL may be very different than Hach's estimate of the detection limit. To test how reasonable the calculated MDL is, repeat the procedure using a standard near the calculated MDL. The average result calculated for the second MDL derivation should agree with the initial calculated MDL. Refer to 40 CFR, Part 136, Appendix B (7-1-94), pages 635–637 for detailed procedures to verify the MDL determination.*

Run a laboratory blank, containing deionized water without analyte, through the test procedure to confirm that the blank measurement is less than the calculated MDL. If the blank measurement is near the calculated MDL, repeat the MDL procedure using a separate blank for analysis for each portion of standard solution analyzed. Subtract the average blank measurement from each standard and use the corrected standard values to calculate the average and standard deviation used in the MDL.

3.4.3 Precision

Every measurement has some degree of uncertainty. Just as a ruler with markings of 1 mm leaves some doubt as to the exact length of a measurement, chemical measurements also have some degree of uncertainty. The quality of the entire calibration curve determines the precision.

Uncertainty in chemical measurements may be due to systematic errors and/or random errors. A systematic error is a mistake that is always the same for every measurement made. For example, a blank can add to each measurement for a specific compound, giving consistently high results (a positive bias). Random errors are different for every test and can add either a positive or negative variation in response. Random errors are most often caused by variation in analytical technique. Hach chemists work hard to eliminate systematic errors in Hach procedures using Hach reagents, but response variation occurs in all chemical measurements.

3.4.4 Estimating Precision

The method performance section in each procedure provides an estimate of the procedure's precision. Two types of estimates are used throughout this book. Most of the procedures use a *replicate analysis* estimate, based on real data. For precision determined in this manner, the 95% confidence interval of the distribution is reported. Some newer procedures use a 95% or 99% *confidence interval*, which is based on the calibration data for that particular chemistry.

In replicate analysis, a Hach chemist prepares a specific concentration of the analyte in a deionized water matrix. The standard is then analyzed seven individual times on a single instrument with the two reagent lots originally used in the calibration (a total of 14 samples). A standard deviation of each of the two sets of seven values is calculated, and the worst-case 95% confidence interval of the distribution is reported in the method. The reported value provides an estimate of the "scatter" of results at a particular point in the calibration curve.

In either case, it is important to realize that the estimates are based on a deionized water matrix. Precision on real samples with varying matrices can be quite different from these estimates.

If the concentration obtained from running a standard solution does not fall within the stated precision, please refer to *Section 3.2.3 Troubleshooting a Test When Results are in Doubt.*

3.4.5 Sensitivity

Hach's definition of sensitivity is the change in concentration (ΔConcentration) for a 0.010 change in absorbance (ΔAbs).

Use sensitivity when comparing different methods. For example, Hach has three DR/2500 methods for determining iron:

Iron Analysis Method	Portion of Curve	ΔAbs	ΔConcentration
FerroVer	Entire range	0.010	0.022 mg/L
FerroZine	Entire range	0.010	0.009 mg/L
TPTZ	Entire range	0.010	0.012 mg/L

Notice that the FerroZine method has the greatest sensitivity of the three methods because it will measure the smallest change in concentration. The technical definition of sensitivity comes from a calibration curve with Abs on the x-axis and concentration on the y-axis.

1. If the calibration is a line, the sensitivity is the slope of the line multiplied by 0.010.
2. If the calibration is a curve, the sensitivity is the slope of the tangent line to the curve at the concentration of interest multiplied by 0.010.

The sensitivity value is also used as an estimate of the lower limit of the test. The value may be used as a starting point in determining MDL.

3.5 Preparing a Calibration Curve

Note: *Calibration curves are recommended when using a non-Hach instrument or where required by a regulator.*

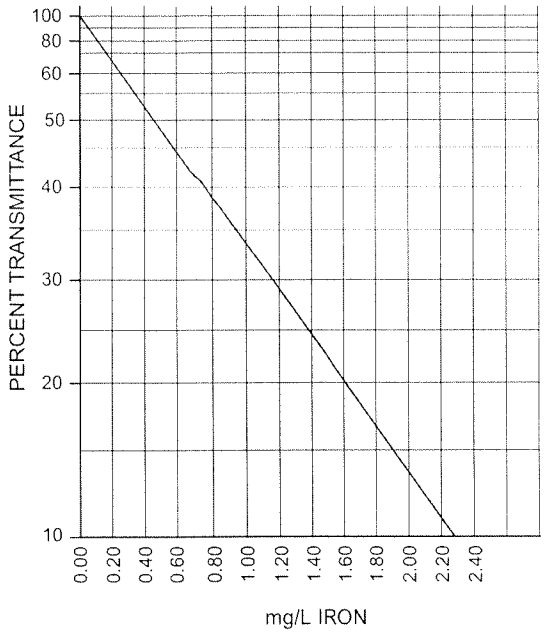
1. Prepare five or more standards of known concentration that cover the expected range of the test. Run tests as described in the procedure on each prepared standard. Then pour the customary volume of each known solution into a separate clean sample cell of the type specified for your instrument.
2. Select the proper wavelength. Standardize (zero) the instrument using an untreated water sample or a reagent blank, whichever the procedure instructs you to use.
3. Measure and record the absorbance of the known solutions within the time constraints detailed in the procedure. To use absorbance vs. concentration, see *Section 3.5.2 Absorbance Versus Concentration Calibration.*

3.5.1 %T Versus Concentration Calibration

If measuring %T, use semilogarithmic graph paper and plot %T (vertical scale) versus concentration (horizontal scale). For *Figure 2*, iron standard solutions of 0.1, 0.2, 0.4, 0.8, 1.2, 1.6 and 2.0 mg/L were measured on a Spectronic® 20* at 500 nm using half-inch test tubes. Results were plotted and the calibration table values were extrapolated from the curve (*Table 2*).

* Spectronic is a registered trademark of Thermo Electron Corporation

Figure 2 Semilogarithmic Calibration Curve



To convert %T readings to concentration, prepare a table such as *Table 2* and select the appropriate line from the "%T Tens" column and the appropriate column from the "%T Units" columns. The %T Ten value is the first number of the % transmittance reading and the %T Units value is the second number of the % transmittance reading. For example, if the instrument reading was 46%, the 40 line in the %T Tens column and the 6 column in the %T Units would be selected. The cell where these two intersect (0.78 mg/L) is the iron concentration of the sample.

Table 2 Calibration Table

	Absorbance Units									
Absorbance Tens	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	–	–	–	–	–	–	–	–	–	–
10	2.30	2.21	2.12	2.04	1.97	1.90	1.83	1.77	1.72	1.66
20	1.61	1.56	1.51	1.47	1.43	1.39	1.35	1.31	1.27	1.24
30	1.20	1.17	1.14	1.11	1.08	1.04	1.02	.99	.97	.94
40	.92	.89	.87	.84	.82.	.80	.78	.76	.73	.71
50	.69	.67	.65	.64	.62	.60	.58	.56	.55	.53
60	.51	.49	.48	.46	.45	.43	.42	.40	.39	.37
70	.36	.34	.33	.32	.30	.29	.28	.26	.25	.24
80	.22	.21	.20	.19	.17	.16	.15	.14	.13	.12
90	.11	.09	.08	.07	.06	.05	.04	.03	.02	.01

3.5.2 Absorbance Versus Concentration Calibration

If absorbance values are measured, plot the results on linear graph paper. Plot the absorbance value on the vertical axis and the concentration on the horizontal axis.

Plot increasing absorbance values from bottom to top. Plot increasing concentration values from left to right. Values of 0.000 absorbance units and 0 concentration will begin at the bottom left corner of the graph. A calibration table can be extrapolated from the curve or the concentration values can be read directly from the graph. Or determine an equation for the line using the slope and y-intercept.

3.6 Adapting Procedures to Other Spectrophotometers

Hach procedures may be used with other spectrophotometers, if calibration curves are made that convert absorbance to concentration. Regardless of the spectrophotometer used, prepare the sample and calibration standards following the Hach procedure and use the optimum wavelength used in the Hach procedure.

To calibrate for a given analyte, a series of standards are prepared and measured to establish the calibration curve. The absorbance vs. concentration is plotted on linear graph paper (as described in *Section 3.5.2 Absorbance Versus Concentration Calibration*). Points on the graph are connected with a smooth line (curved or straight). If necessary, use the curve to make a calibration table.

3.6.1 Selecting the Best Wavelength

When developing a new procedure, or using procedures that are sensitive to wavelength, it is normal to select the wavelength where the instrument gives the greatest absorbance (see *Figure 3*). Because Hach chemists have selected the best wavelength for the procedures in this book; selecting the wavelength is not necessary for most procedures.

3.6.1.1 General steps to select the best wavelength on a spectrophotometer:

1. Refer to the instrument manual for specific instructions for wavelength adjustments.
2. Select single wavelength adjustment.
3. Enter a wavelength in the range of interest.

Note: *Sample color provides a good indication of what wavelength region to use. A yellow solution absorbs light in the 400–500 nm region. A red solution absorbs light between 500–600 nm. A blue solution absorbs light in the 600–700 nm range.*

4. Prepare the sample and blank for analysis. Fill the appropriate sample cells with the blank and the reacted sample solution.
5. Place the blank in the cell holder. Zero the instrument.
6. Place the prepared sample into the cell holder. Read the absorbance level.
7. Increase the wavelength so it is at least 100 nm greater than the range of interest. Re-zero as in step *5*. Measure and record the absorbance of the sample.
8. Repeat, decreasing the wavelength by 50 nm. Re-zero, then measure and record the absorbance at each increment. Continue this process throughout the wavelength range of interest. Note the wavelength of greatest absorbance. (See *Table 3*.)

Table 3 Example

Wavelength	Absorbance
550 nm	0.477

Table 3 Example

Wavelength	Absorbance
500 nm	0.762
450 nm	0.355
400 nm	0.134

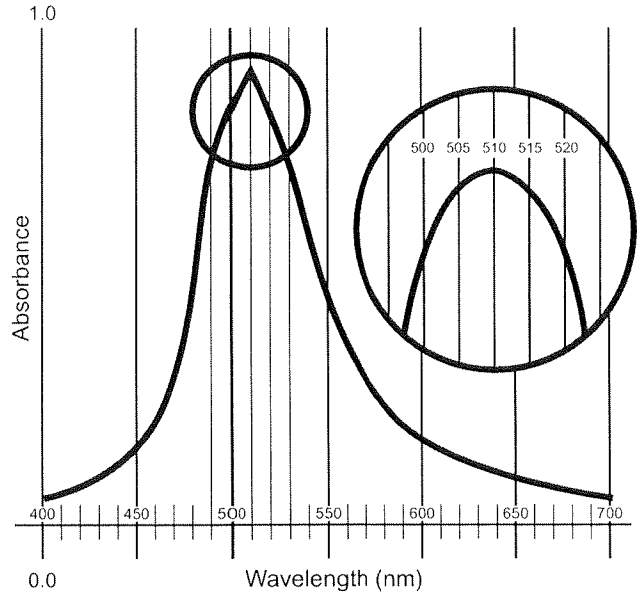
9. Adjust the wavelength to 50 nm more than the highest absorbance point on the initial search (step *8*). Re-zero as in step *5*.
10. Measure and record the absorbance. Repeat, decreasing the absorbance in 5-nm steps. Re-zero, then measure and record the absorbance at each increment. Continue until the entire range of interest is measured (see *Table 4*).

Table 4 Example

Wavelength	Absorbance
520 nm	0.748
515 nm	0.759
510 nm	0.780
505 nm	0.771
500 nm	0.771
495 nm	0.651
490 nm	0.590

Check to be sure there is enough difference in absorbance between samples with low and high analyte concentrations by measuring two sample solutions that contain the expected low and high concentrations of analyte at the optimum wavelength. The change in absorbance caused by increases/decreases in concentration depends on the sensitivity of the procedure and the chemistry. Chemistries with small absorbance changes are less sensitive, but tend to have larger ranges. Chemistries with large absorbance changes are more sensitive, but tend to have smaller ranges.

Figure 3 Selecting the Best Wavelength



Adapting a Buret Titration for Use With a Digital Titrator

Any standard titration procedure that uses a buret can be adapted to the Digital Titrator by using the following procedure.

1. From *Table 5* on page *39*, select a titration cartridge having the same active ingredient as the buret solution.
2. Determine the approximate number of digits required. The Digital Titrator dispenses 1 mL per 800 digits on the counter. Using the following equation, determine the digits required for your buret method.

$$\text{Digits Required} = \frac{N_t \times mL_t \times 800}{N_c}$$

Where:

N_t = Normality of buret titrant

mL_t = milliliters of buret titrant required for an average titration

N_c = Normality of Digital Titrator cartridge.

If the number of digits required is within the range of 70 to 350, you can use the procedure as written, substituting the Digital Titrator directly for the buret.

Or, if the number of digits is outside of this range, make the following modifications:

a. If the number of digits required is greater than 350, decrease the sample size to save titrant.
b. If the number of digits required is less than 70, increase the sample size to increase precision.
c. If the sample size is altered, adjust the amount of buffering or indicating reagents by the same proportion.

3. When using the Digital Titrator for your buret method, note the number of digits required for a sample titration. To convert the digits required to the equivalent number of milliliters for a buret method, calculate:

$$\text{Equivalent Buret Milliliters} = \text{Digits Required} \times \frac{N_c}{800 \times N_t}$$

If the sample size was changed, adjust the equivalent buret milliliters accordingly. If the sample size was increased, reduce the equivalent buret milliliters; if the sample size was reduced, increase the equivalent buret milliliters. Multiply the equivalent buret milliliters by any normally used factors to calculate concentration in oz./gal, g/L, etc.

Example: Adapt a buret procedure that normally requires about 20 mL of a 0.4 N titrant to the Digital Titrator. Try an 8.0 N titration cartridge. The first equation above gives:

$$\text{Digits Required} = \frac{0.4 \times 20 \times 800}{8.0} = 800 \text{ digits}$$

Because this would use excessive titrant, reduce the sample size to one-fourth its normal size to reduce the digits required to 200, well within the recommended range.

Upon completion of the titration using the smaller sample size, calculate the equivalent buret milliliters by the second equation above.

If 205 were the digits required:

$$\text{Equivalent Buret Milliliters} = \frac{205 \times 8.0}{800 \times 0.4} = 5.13 \text{ mL}$$

Multiply the resulting 5.13 mL by four to account for the reduction in sample size and give the true equivalent buret milliliters of 20.5 mL. If the buret method called for multiplying the number of milliliters of titrant by a factor to calculate the concentration of a sample component, then multiply 20.5 by that factor.

Table 5 Titration Cartridges

Description	Cat. No.
Bismuth Nitrate, 0.0200 M	24345-01
CDTA, 0.800 M, HexaVer	14403-01
Ceric Standard Solution, 0.5N	22707-01
EDTA, 0.0800 M, TitraVer	14364-01
EDTA, 0.142 M	14960-01
EDTA, 0.714 M	14959-01
EDTA, 0.800 M, TitraVer	14399-01
FEAS, ferrous ethylenediammonium sulfate, 0.00564 N	22923-01
Hydrochloric Acid, 8.00 N	14390-01
Iodate-Iodide, potassium, 0.3998 N	14961-01
Iodate-Iodide, potassium, 1.00 N	22944-01
Magnesium Chloride, 0.0800 N	20625-01
Mercuric Nitrate, 0.2256 N	14393-01
Mercuric Nitrate, 2.256 N	921-01
Mercuric Nitrate, 2.57 N	23937-01
PAO, phenylarsine oxide, 0.00451 N	22599-01

Table 5 Titration Cartridges (continued)

Description	Cat. No.
PAO, phenylarsine oxide, 0.0451 N	21420-01
Potassium Dichromate, 1.00 N	21971-01
Silver Nitrate, 0.2256 N	14396-01
Silver Nitrate, 1.128 N	14397-01
Sodium Hydroxide, 0.1600 N	14377-01
Sodium Hydroxide, 0.1612 N	24280-02
Sodium Hydroxide, 0.3636 N	14378-01
Sodium Hydroxide, 0.9274 N	14842-01
Sodium Hydroxide, 1.600 N	14379-01
Sodium Hydroxide, 3.636 N	14380-01
Sodium Hydroxide, 0.9274 N	14842-01
Sodium Hydroxide, 8.00 N	14381-01
Sodium Thiosulfate, 0.00451 N	24086-01
Sodium Thiosulfate, 0.0451 N	24095-01
Sodium Thiosulfate, 0.02256 N	24091-01
Sodium Thiosulfate, 0.0250 N	24093-01
Sodium Thiosulfate, 0.113 N	22673-01
Sodium Thiosulfate, 0.2000 N	22675-01
Sodium Thiosulfate, 0.2068 N	22676-01
Sodium Thiosulfate, 2.00 N	14401-01
Sodium Vanadate, 0.25 N	22949-01
Sulfuric Acid, 0.1600 N	14388-01
Sulfuric Acid, 1.600 N	14389-01
Sulfuric Acid, 8.00 N	14391-01
TitraVer, 0.0716 M	20817-01
TitraVer, 0.716 M	20818-01

3.7 Comparison of International Drinking Water Guidelines

Table 6 Comparison of International Drinking Water and FDA Bottled Water Guidelines*

Parameter	USEPA** Maximum Contaminant Level (MCL)	Canada*** Maximum Acceptable Concentration	EEC**** Maximum Admissible Concentration	Japan***** Maximum Admissible Concentration	WHO****** Guideline	Bottled Water U.S. Federal Drug Administration Level
Aluminum	0.05–0.2 mg/L*******		0.2 mg/L	0.2 mg/L	0.2 mg/L	
Ammonium			0.5 mg/L	No standard	1.5 mg/L	
Antimony	0.006 mg/L		0.01 mg/L	0.002 mg/L********	0.005 mg/L	
Arsenic	0.05 mg/L	0.025 mg/L	0.05 mg/L	0.01 mg/L	0.01 mg/L	0.05 mg/L
Barium	2.0 mg/L	1.0 mg/L	No standard	No standard	0.7 mg/L	2.0 mg/L
Boron		5.0 mg/L	1.0 mg/L	0.2 mg/L[8]	0.3 mg/L	
Cadmium	0.005 mg/L	0.005 mg/L	0.005 mg/L	0.01 mg/L	0.003 mg/L	0.005 mg/L
Chloride	250 mg/L[7]	250 mg/L	250 mg/L	200 mg/L	250 mg/L	
Chromium	0.1 mg/L	0.05 mg/L	0.05 mg/L	0.05 mg/L	0.05 mg/L	0.1 mg/L
Coliforms, total Organisms/100 mL	≤% positive	0	0 or MPN ≤1	0	0	≤1 MF
Coliforms (*E. coli*) Organisms/100 mL	0	0	0	0	0	
Color	15 cu[7]	15 cu	20 mg Pt-Co/L	5 cu	15 cu	<15 cu
Copper	1.3 mg/L[7]	1.0 mg/L	2.0 mg/L	1.0 mg/L	1–2 mg/L	1.0 mg/L
Cyanides	0.2 mg/L	0.2 mg/L	0.05 mg/L	0.01 mg/L	0.07 mg/L	
Fluoride	2.0-4.0 mg/L[7]	1.5 mg/L	0.7-1.5 mg/L	0.8 mg/L	1.5 mg/L	
Hardness			50 mg/L	300 mg/L		
Iron	0.3 mg/L[7]	0.3 mg/L	0.2 mg/L	0.3 mg/L	0.3 mg/L	
Lead	0.015 mg/L	0.01 mg/L	0.01 mg/L	0.05 mg/L	0.01 mg/L	0.005 mg/L
Manganese	0.05 mg/L	0.05 mg/L	0.05 mg/L	0.01–0.05 mg/L	0.1–0.5 mg/L	
Mercury	0.002 mg/L	0.001 mg/L	0.001 mg/L	0.0005 mg/L	0.001 mg/L	0.002 mg/L
Molybdenum				0.07 mg/L	0.07 mg/L	
Nickel	0.1 mg/L		0.02 mg/L	0.01 mg/L[8]	0.02 mg/L	
Nitrate/Nitrite, total	10.0 mg/L as N			10.0 mg/L as N		10 mg/L as N
Nitrates	10.0 mg/L as N	10.0 mg/L as N	50 mg/L	10 mg/L as N	50 mg/L as NO_3^-	
Nitrites	1 mg/L as N	3.2 mg/L	0.1 mg/L	10 mg/L	3 mg/L as NO_2^-	1 mg/L as N
Odor	3 TON*********		2 dilution no. @ 12 °C; 3 dilution no. @ 25 °C.	3 TON		
pH	6.5–8.5	6.5–8.5	6.5–9.5	5.8–8.6	6.5–8.5	
Phosphorus			5 mg/L	No Standard		
Phenols		0.002 mg/L	0.5 µg/L C_6H_5OH	0.005 mg/L		
Potassium			12 mg/L	No Standard		
Selenium	0.05 mg/L	0.01 mg/L	0.01 mg/L	0.01 mg/L	0.01 mg/L	0.05 mg/L
Silica Dioxide			10 mg/L	No Standard		
Silver	0.1 mg/L[7]	0.05 mg/L	0.01 mg/L	No standard	No standard	

Table 6 Comparison of International Drinking Water and FDA Bottled Water Guidelines* (continued)

Parameter	USEPA** Maximum Contaminant Level (MCL)	Canada*** Maximum Acceptable Concentration	EEC**** Maximum Admissible Concentration	Japan***** Maximum Admissible Concentration	WHO****** Guideline	Bottled Water U.S. Federal Drug Administration Level
Solids, total dissolved	500 mg/L[7]	500 mg/L	No standard	500 mg/L	1000 mg/L	
Sodium			75-150 mg/L	200 mg/L	200 mg/L	
Sulfate	250 mg/L[7]	500 mg/L	250 mg/L	No Standard	250 mg/L	
Turbidity	0.5-5 NTU	1 NTU	4 JTU	1–2 units	5 NTU	<5 NTU
Zinc	5 mg/L[7]	5.0 mg/L	No Standard	1.0 mg/L	3.0 mg/L	

* To our knowledge, data in this table were accurate and current at the publication date. Contact the regulatory agency in your area for the most current information.

** United States Environmental Protection Agency.

***These limits are established by Health Canada.

****In the EEC (European Economic Community), these limits are set by the European Committee for Environmental Legislation.

*****In Japan, these limits are established by the Ministry of Health and Welfare.

******World Health Organization.

*******U.S. Secondary MCL.

********Identified as a parameter to be regulated in the future.

*********Threshold Odor Number.

3.7.1 Definitions of USEPA Approved and Accepted

USEPA Approved

The United States Environmental Protection Agency (USEPA) establishes limits for maximum contamination levels of certain constituents in water. It also requires that specific methodology be used to analyze for these constituents. Sometimes the USEPA develops these methods; more often, the USEPA evaluates methods developed by manufacturers, professional groups, and public agencies such as:

- American Public Health Association
- American Water Works Association
- Water Environmental Federation
- American Society for Testing and Materials
- United States Geological Survey
- Association of Official Analytical Chemists

When a method meets the USEPA criteria, it is *approved.* All USEPA approved methods are cited in the *Federal Register* and compiled in the *Code of Federal Regulations.* USEPA-approved methods may be used for reporting results to the USEPA and other regulatory agencies.

USEPA Accepted

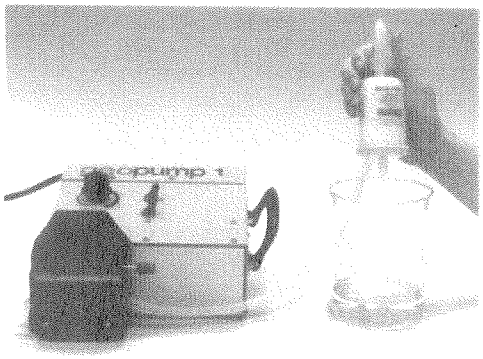
Hach has developed several procedures that are equivalent to USEPA approved methods. Even though minor modifications exist, the USEPA has reviewed and accepted certain procedures for reporting purposes. These methods are not published in the *Federal Register,* but are referenced to the equivalent USEPA method in the procedure.

Geopump™ Peristaltic Pumps

The Geotech Series I and II Geopump™ Peristaltic Pumps are designed for single and multi-stage pressure or vacuum pumping of liquids. The Geopump is ideally suited for field sample removal from shallow wells and all surface water sources or laboratory use.

- Exceptional field durability
- Operate from 60 to a maximum of 600 RPM
- Delivery rate of 1.67 ml per revolution
- Operate to a depth of 27 feet at sea level
- Variable speed control
- Reversible flow feature for back-flushing
- Disposable and dedicated tubing means controlled costs and no decontamination issues

Geopump™ Peristaltic Pump Series II with EZ-load 2 pump head (optional), 5 ft tubing, carrying case and power cord



Geopump™ Peristaltic Pump Series I with EZ-load 2 pump head (optional) and dispos-a-filter capsule

Operation

The Geotech Peristaltic Pumps operate by mechanical peristalsis, so the sample only comes in contact with the tubing. This allows for sample integrity as well as easy cleaning and replacement. With the optional stainless steel tubing weight, tubing can be lowered to a specific depth without curling or floating on the surface of the water. Geopumps operate from any external 12 VDC or 120 VAC power source.

SERIES II Geopump™ Peristaltic Pumps are available in AC only, DC only, or an AC/DC combination. They have two pumping stations which can also be piggy-backed for multi-station pumping. The first pumping station has a variable speed of 30 to 300 RPM and the second station 60 to 600 RPM.

SERIES I Geopump™ Peristaltic Pumps are available in AC only, DC only, or an AC/DC combination. These units have one pumping station which can be piggy-backed for multi-station pumping. They have variable speeds ranging from 60 RPM to 350 RPM.

HF Scientific MicroTPI and MicroTPW Portable Turbidity Meters

- **Rugged Portable Carrying Case** - Ensures durability and convenience no matter where your sample happens to be
- **Waterproof** - Waterproof housing allows sample measuring and cleaning in any wet environment
- **Completely Self Contained** - Contains everything you need, including, battery pack, sample cells, manual, and calibration standards
- **Auto Ranging 0 - 1100 NTU** - Senses turbidity and automatically adjusts to the appropriate measurement scale
- **Simple Calibration Procedures**
- **Economical Cost**
- **Over 1000 Tests on a single set of 4 - AAA alkaline batteries**
- **Laboratory Accuracy**
- **Made in the USA**

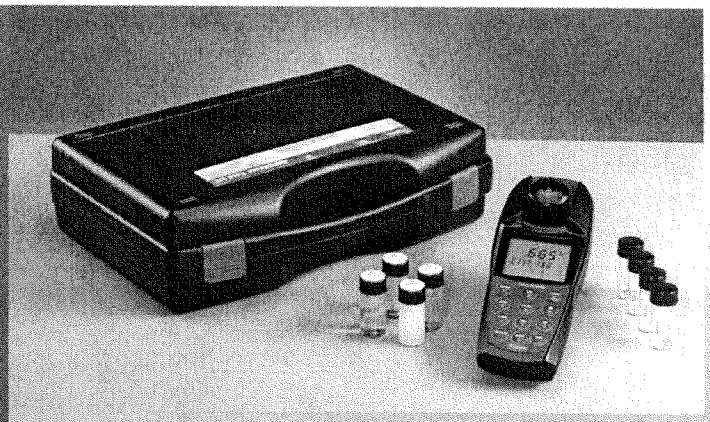
Designed to provide the ease of portability needed in the field with rugged durability. The MicroTPI and MicroTPW are a "must have" for anyone monitoring turbidity on the go. The shock-resistant carrying case holds everything needed for field operation while the instrument itself removes easily to go wherever you need it. With resolution of 0.01 NTU and an extended range to 1,100 NTU, the MicroTPI and MicroTPW are perfect for field use.

HF SCIENTIFIC MICROTPI & MICROTPW SPECIFICATIONS

Conformance:	ISO 70727, USEPA Method 180.1
Measurement Range:	Auto - Ranging from 0 - 1100 NTU
Principle of Operation:	Nephelometric
Certification:	CE, NEMO 4x, Designed to meet IP67
Accuracy:	
(0-500 NTU)	± 2% of reading or ± 0.01 NTU
(500-1100 NTU)	± 3% of reading
Resolution:	0.01 NTU < 10 NTU 0.1 NTU < 100 NTU 1 NTU < 1100 NTU
Response Time:	6 to 16 seconds
Display:	4 Digit (7 segment) LCD
Light Source:	
(TPI)	IR - LED (860 nm)
(TPW)	White Light (Tungsten lamp compliant)
Power Supply:	4 - AAA Alkaline Batteries (over 1000 Tests)
Sample Cells:	10mL
Materials:	
(Instrument)	ABS - Injection molded
(Carry Case)	High density Polyethylene blow molded
Shipping Dimensions:	11 x 12 x 3 inches (28 x 30.5 x 7.6 cm)
Shipping Weight:	2.7 lbs (1.22 kg)

Thermo Electron Orion AQUAFast AQ4500 Turbidimeter

Thermo Electron introduces the Orion AQ4500 Turbidimeter which offers advanced features not available on any other benchtop or portable turbidimeter. The AQ4500 offers a dual source LED which allows readings that comply with both EPA 180.1 and ISO 7027. Turbidity can be read in the range of 0 - 1000 NTU with a choice of units: NTU, FTU, FNU, ASBC, and EBC. In the range of 0 - 40 NTU the AQ4500 offers a ratiometric range which will give EPA, GLI method 2 equivalent numbers. This portable field unit is truly IP67 waterproof with typical battery life over 1000 hours on one set of batteries and datalog capacity of 100 points which can later be downloaded to a printer or computer. The AQ4500 accepts 24 mm cuvettes and comes with a two year warranty.



Thermo
ELECTRON CORPORATION

- Nephelometric and Ratiometric measurements with Autoranging
- Data log capacity of up to 100 data points
- Readings in the range of 0 - 1000 NTU with a choice of units: NTU, FTU, FNU, ASBC, or EBC
- Includes Turbidity Standards kit, rugged carrying case, and replacement cuvettes
- Orion AQ4500 is truly IP67 waterproof to a depth of 3 meters

ORION AQUAFAST AQ4500 SPECIFICATIONS

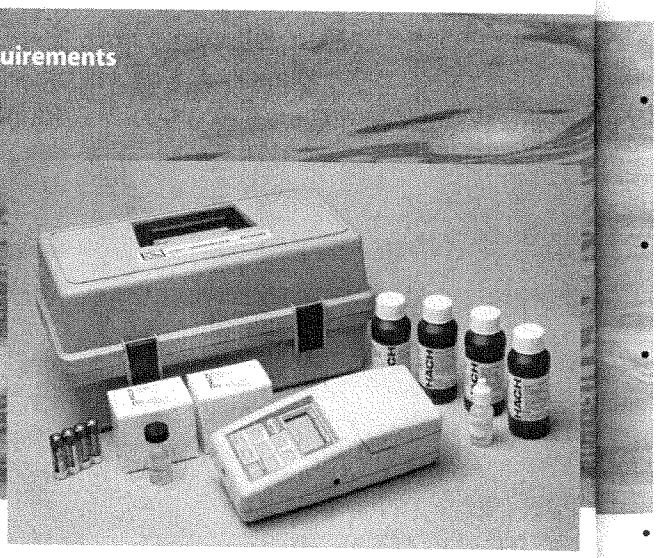
Type	Turbidity Meter
Principle of Operation	Nepeholmetric
Operating Modes	Automatic
Measurement Modes	Automatic
Ranges	
NTU	0–2000
Nephelometric	0–4000
EPA	0–4000 NTU
ISO - NEPH (7027)	0–150 FNU
ISO - ABSB	40–4000 FAU
IR RATIO	0–4000 NTU
EBC	0–24.5
ASBC	0–236
Accuracy	± 2% of reading plus 0.01NTU (0–500 NTU) ± 3% of reading (500–1000 NTU) ± 5% of reading (1000–2000 NTU)
Resolution	0.01 NTU (0–9.99) 0.1 NTU (10–99.9) 1 NTU (100–1000)
Repeatability	± 1% of reading or 0.01 NTU
Response Time	< 8 seconds
Calibration	1, 10, 100, 1000 NTU
Signal Averaging	Yes
Sample Cell Size	24 mm
Sample Size	12 mL
Display	Custom LED
RTC	Yes
Input/Output	RS 232 Serial Port
Power	Battery - four AA's (2,500 hr Alkaline, 10,000 lithium)
Environmental Conditions	
Operating Temperature	-40° to 140°F (-40° to 60°C)
Humidity	90% RH at 30.0C max
Light Source	White, IR
Warranty	2 years
Weight	8 lbs (3.63 kg)
Safety Rating	UL, CSA, CE, FCC

1-800-833-7958 www.geotechenv.com fax 303-322-7242 sales@geotechenv.com

Hach 2100P
Portable Turbidimeter

The Hach 2100P Portable Turbidimeter measures turbidity of water using microprocessor controlled operation and patented ratio optics. It is ideal for regulatory monitoring, process control or field studies.

- **Meets EPA performance requirements**
- **Lightweight, rugged design**
  Weighs less than one pound and comes ready to use.
- **Auto-Range or 3 manual ranges available**
- **Built-in diagnostic mode**
- **Rental units available - *Call Today!***



Calibration and Standardization
Calibration of the 2100P Portable Turbidimeter is based on Formazin, the accepted primary standard for turbidity measurement. For convenient routine verification, Geotech supplies Gelex® Secondary Standards (metal oxide particles locked in gel) formulated to simulate Formazin. When checked periodically against Formazin, these secondary standards are a simple and accurate means of checking instrument calibration.

Built-in Diagnostics
The diagnostic mode is accessible with one key stroke. This mode allows the operator to obtain information about operating parameters that can help evaluate instrument functions.

Electronic Zero
When the READ key is pressed, the 2100P Portable Turbidimeter automatically zeros the instrument, compensating for stray light and electronic and optical offsets. No manual adjustment is required.

Two-Year Warranty
Hach warrants the 2100P Portable Turbidimeter against defective materials or workmanship for two years from the date of purchase.

HACH 2100P PORTABLE TURBIDIMETER SPECIFICATIONS

Ranges	
automatic range mode	0-1000 NTU
manual range	0-9.99 NTU
manual range	0-99.9 NTU
manual range	0-1000 NTU
Accuracy	±2% of reading or ±1 significant digit
Accuracy at 500-1000 NTU	±3% of reading
Repeatability	±1% of reading or ±0.01 NTU, which ever is greater
Resolution	0.01 NTU on lowest range
Stray light	£0.02 NTU
Sample Required	15 mL
Power Requirement	four AA alkaline batteries or optional 120 or 230V AC battery eliminator
Construction	high impact ABS plastic shell
Dimensions	22.0 x 9.5 x 8.9 cm (8.75 x 3.75 x 3.5 inches)
Shipping Weight	3.6 kg (8 lbs.)
Warranty	Two years

ANALYTICAL

YSI 556 MPS
Multi-Probe Field Meter

The YSI 556 MPS simultaneously measures dissolved oxygen, pH, conductivity, temperature, ORP, and more. The YSI 556 combines the versatility of an easy-to-use, easy-to-read handheld unit with all the functionality of a multiparameter system.

- Field replaceable DO, conductivity, and pH/ORP electrode modules.
- Easy-to-use screw-on cap DO membranes.
- 4, 10 and 20 meter cable lengths available.
- Stores over 49,000 data sets, time and date stamped. Easy download to PC.
- Standard soft-sided carrying case with enough space for the YSI 556, 20-meter cable and calibrating supplies.
- Probe guard protects sensors for down-well or open channel readings.

1-800-833-7958 www.geotechenv.com fax 303-322-7242 sales@geotechenv.com

YSI 556 MPS SPECIFICATIONS

Size:	11.9cm width x 22.9 cm length (4.7 in. x 9 in.)
Weight w/ batteries:	2.1lbs
Power:	4 alkaline C-cells; optional rechargeable pack
Cables:	13.1, 32.8 and 65.6 ft. lengths
Warranty:	3 year for the instrument 1 year for the probe module
Options:	Flowcell Hard-sided carry case

YSI 556 SENSOR SPECIFICATIONS

	Sensor type:	Range:	Accuracy:	Resolution:
Dissolved Oxygen (% saturation)	Steady state polarographic	0 to 500% air sat.	0 to 200% air sat.; ±2% of the reading or 2% air sat. whichever is greater; 200 to 500% air sat., ±6% of the reading	0.1% air sat.
Dissolved Oxygen (mg/L)	Steady state polarographic	0 to 50 mg/L	0 to 20mg/L: ± 2% of the reading or 0.2mg/L whichever is greater. 20 to 50 mg/L ±6% of the reading	0.01 mg/L
Temperature	YSI precision Thermistor	-5 to 45°C	±0.15°C	0.1°C
Conductivity	4-electrode cell with autoranging	0 to 100mS/cm	±0.5% of reading +0.002mS/cm	0.001 mS/cm to 0.1 mS/cm (range dependent)
Salinity	Calculated from Cond. and Temp.	0 to 70 ppt	± 1.0% of reading or 0.1ppt whichever is greater	0.01 ppt
pH	Glass combination electrode	0 to 14 units	±0.2 units	0.01 units
ORP	Platinum button	-999 to +999 mV	±20 mV	0.1 mV
Barometer (optional)		500 to 800 mm Hg	±3 mm Hg within ± 15°C temp. range from calibration point	0.1 mm Hg
TDS	Calculated from cond. based on TDS value of calibration solution	User dependent	0.001 g/L	User dependent
Resistivity	Calculated from conductivity reading	Measured in KOhm*cm, user dependent	±0.5% of reading	

YSI 556 MPS with Kit and optional flowcell

Geotech offers technical support as well as annual calibration and cleaning service for all meters!

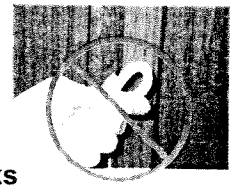
Quick Reference

WL15 Level Logger

Pressure Transducer, Data Logger and Palm Pilot
with customized software for both PalmOS and Windows.
Records Level, Flow, and Pressure at regular intervals.

Basic Setup & Operation:

- Ensure that the cable is handled & stored with large loops and NOT KINKED (which blocks the barometric compensation tube).

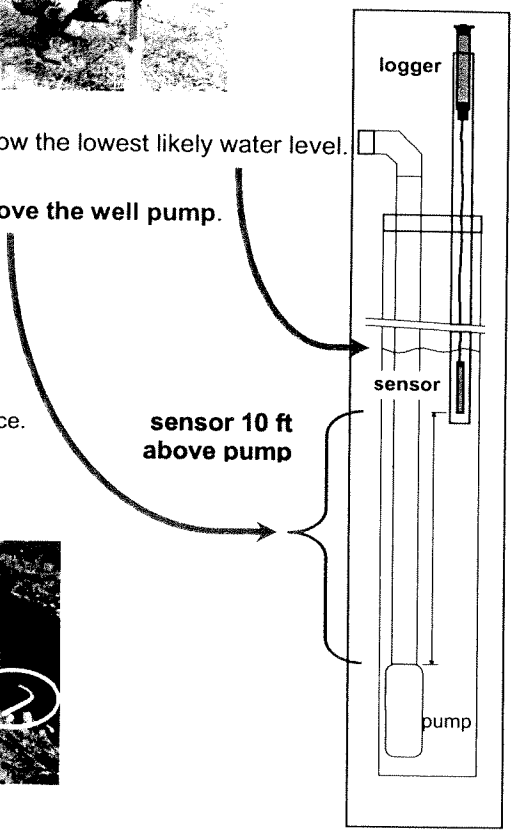


Big Loops, No Kinks

Cable Too Long?
Refer to operations manual or website for tips on how to safely cope with extra cable.

- The Data Logger intentionally fits into 2-inch PVC pipe. If the well casing is larger, simply use a reducer to accomodate a short section of 2-inch pipe to house the Data Logger. A locking, protective metal Well Cap is optionally available.

- It is not necessary to locate the sensor at the well's bottom – merely below the lowest likely water level.
- Avoid error & cable entanglements by installing sensor **at least 10 ft above the well pump**.



A Note on Battery Life:

Although the 9-volt battery in the Logger will last months when in normal use, the connection to computer or Palm to collect readings is highly draining. Limit the length of data collection sessions so that battery life is conserved. We HIGHLY recommend the use of Lithium batteries for their improved performance. Consider your timing of battery changes to maximize Logger performance.

Open-Channel Installations:

- Keep debris, silt or mud away from sensor (eg: Open Channel installations) by housing sensor in **perforated conduit** or wellscreen.

- **Use Long-Sweep Elbows** (PVC conduit fittings) to ease cable deployment through conduit for riverbank monitoring of flow / level in open channels.

Global Water
The Leader in Water Instrumentation

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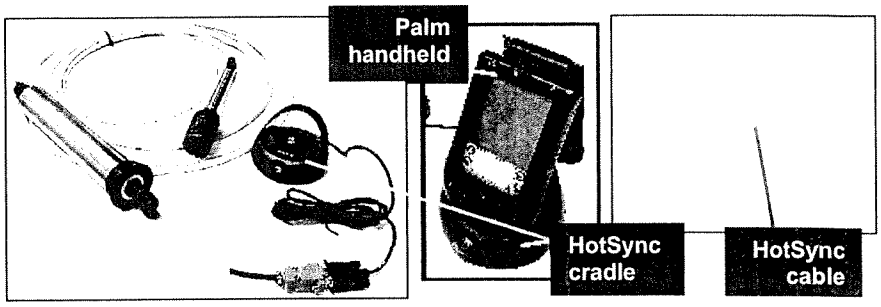
International: 916 638-3429
Fax: (916) 638-3270
Email: globalw@globalw.com

Visit our online catalog at
www.globalw.com
11257 Coloma Road
Gold River, CA 95670 USA
7:30 AM to 4 PM PST

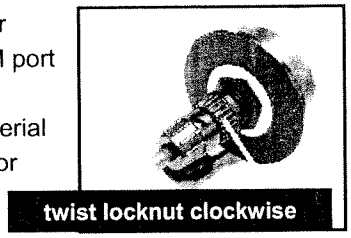
Communications Connections

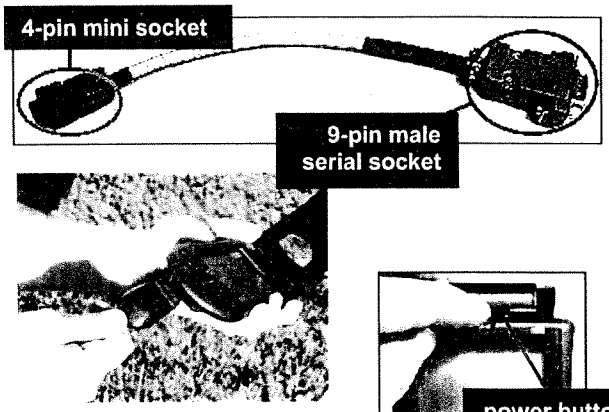
- Note the different cable connections used to enable communications between your Global Level Logger and the Palm handheld. The Palm may be connected to either the HotSync Cradle or Cable, depending on convenience in the office, lab or field. Ensure that each connection is secure.



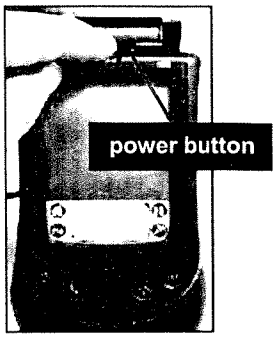
1. Connect short adaptor cable to WL15's COM port

2. Connect 9-pin male serial socket of short adaptor cable to HotSync Cable (or Cradle).



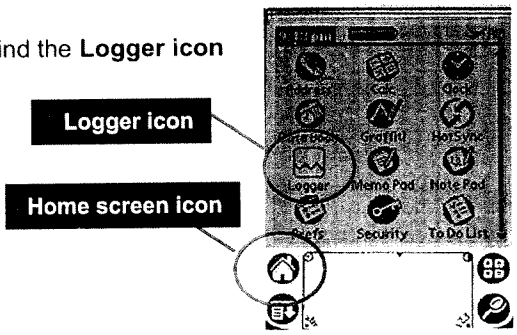


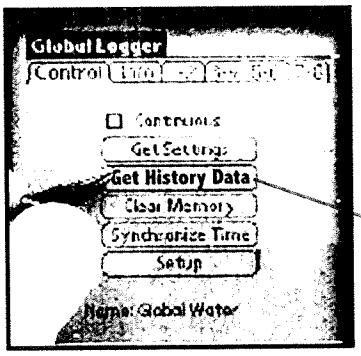
3. Connect HotSync cable to the Palm handheld (or place Palm in its Cradle).



Palm Operation Basics

4. **Turn on power** of Palm handheld and find the **Logger icon** to launch the Global Logger Software (found on Home screen).





5. From the Control Screen, **tap "Get History Data"** to display the accumulated readings. These readings may be saved to a database within the Palm, or kept in the Logger's memory or deleted.
Please see Operator's Manual for more detailed configuration and operating instructions.

Also:

- Overly-frequent archiving of data causes rapid depletion of battery life in the Data Logger.
- If performing a Contiuous Data Check, limit session to ONE MINUTE ONLY. (This data is NOT saved.)
- **If the Palm's battery drains completely (or is not replaced within 15 sec of removal), the Global Logger software (and all data files) will be lost & must be re-installed.**

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